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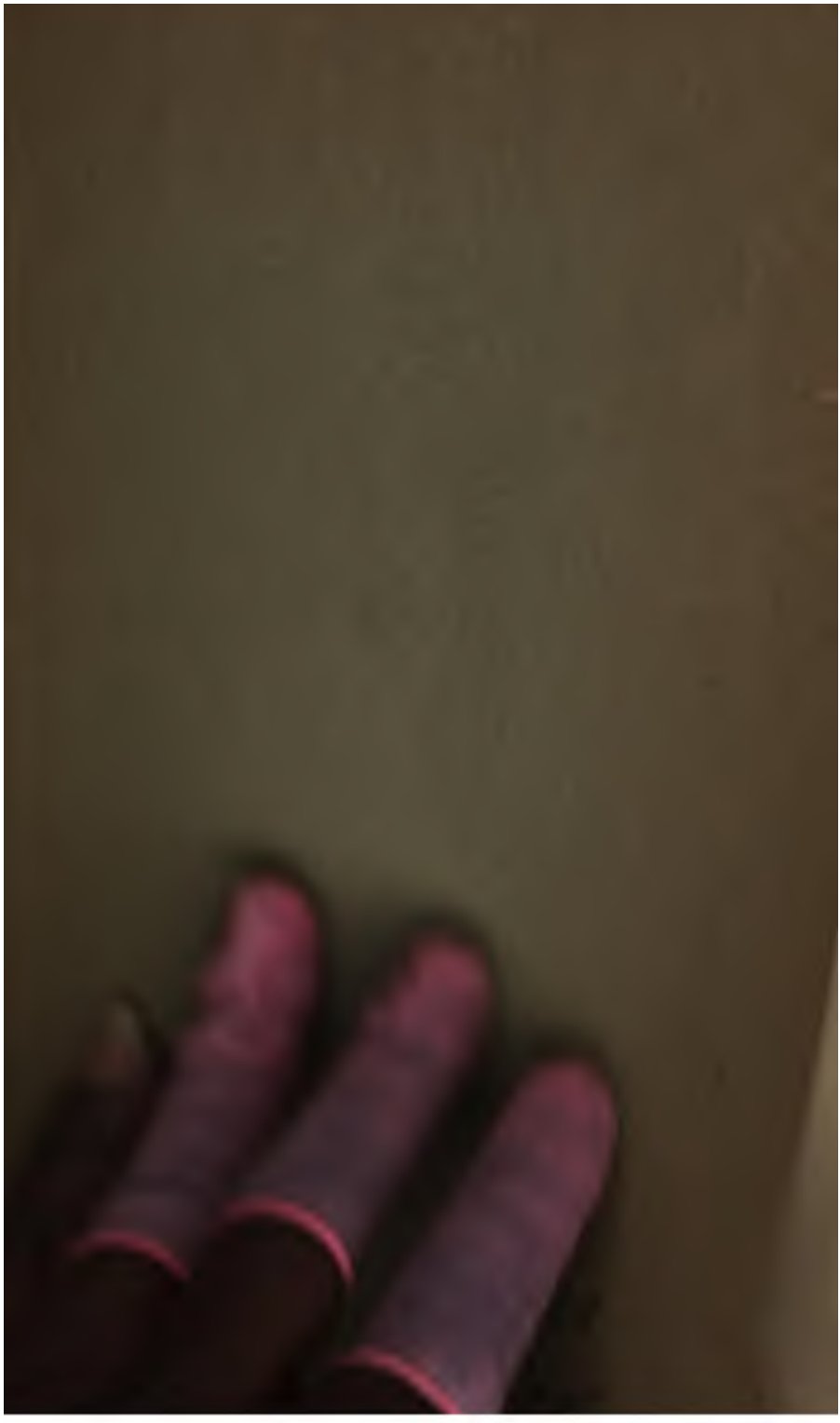
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No. I.—1889.

CONTENTS.

	PAGE
List of New Members	1
Report of the Council	3
President's Address	13
Presentation of Bessemer Medal for 1889	38
On Alloys of Nickel and Steel. By James Riley	45
On the Manufacture of Basic Open-Hearth Steel. By J. H. Darby	78
On the Progress Made in the German Iron Industry since the Year 1880. By E. Schroedter	112
On the Influence of Copper on the Tensile Strength of Steel. By Dr. E. J. Ball and Mr. A. Wingham	123
On Universal Rolling Mills for the Rolling of Girders and Cruciform Sections. By Hugo Sack	132
On the Application of Thermal Chemistry to Metallurgical Reactions. By A. Pourcel	152
Invitation to the Institute to Visit Alabama	177
On the Thomasset Testing Machine. By F. Gautier	184

APPENDIX.

The Financial Statement for 1888 204

Notes on the New Iron Region of Alabama. By Major Burke . . 205

Obituary—Dr. John Percy, 210; Sir William Pearce, 213; Major-General Kalakoutsky, 215; Richard Peacock, 217; James Howard, 218; John Musgrave, 218; John M'Millan, 218; Thomas James, 219; E. A. Jeffreys, 220; John Lloyd, 221; E. J. Grice, 221; Colonel Peter Greck, 222; J. P. Roe, 222.

NOTES ON THE

PROGRESS OF THE HOME AND FOREIGN IRON AND STEEL INDUSTRIES.

SECTION I.—1889.

IRON ORES.

I.—OCCURRENCE AND COMPOSITION.

	PAGE
Iron Ore in New South Wales	226
Loadstone in Sweden	227
Iron Ore in Borneo	227
Iron Ore in Burmah	229
Iron Ore in Mexico	229
The Iron Ores of Michigan and Wisconsin	230
The Iron Ores of Minnesota	232
Iron Ores near Bristol, Tennessee	233
Iron Ores from the Vermilion Range	234
The St. Croix Range, Wisconsin	234
Manganese Ores in Greece	235
A Russian Manganese Ore	235
Formation of Deposits of Manganese Ore	235
Artificial Production of Chrome Iron Ore	236
Recent Researches on Meteorites	236

II.—IRON ORE MINING.

Iron Ore Mining at Bilbao	239
Sinking through Quicksand	239
Rock Drills	240

III.—MECHANICAL PREPARATION.

Concentration of Iron Ore at Norberg	240
The Buchanan Magnetic Rolls	243
The Wenström Magnetic Separator	243
The Edison Magnetic Ore Separator	244

III.—METALLURGICAL PREPARATION.

PAGE
Roasting Hudson River Carbonates 245

REFRACTORY MATERIALS.

Durability of Ganister Bricks 249
Firebricks of Clay and Asbestos 249
Limestone in Lower Silesia 249

FUEL.

I.—CALORIFIC VALUE.

Determination of Calorific Value of Coal 250
A New Pyrometric Method 250
A New Pyrometer 251

II.—COAL.

Analyses of Coal 251
Coal Mining in Spain 251
Coal Mining in Servia 255
The Coalfields of Madagascar 256
Coal in South Africa 256
Coal in New South Wales 256
Coal Discoveries in South Australia 257
The Coal Deposits of the Tennessee Valley 257
Coal in Alaska 257
Coal Mining in Kentucky 257
Coal Deposits in the South Appalachian Field 258
Coal Deposits of the Southern United States 258
German Lignite 259
New Fossil Resins from the Coal Measures 260
Utilisation of Refuse Fuel 260

III.—CHARCOAL.

Proportion of Ash and Phosphorus in Charcoal 261
The Pierce Charcoal Process 262
The World's Consumption of Charcoal 262

IV.—COKE.

Heating Coke Ovens by Natural Gas 263
The Adams Coke Oven Bottom 263
A Coke Screening Machine 263

V.—LIQUID FUEL.

PAGE
Genesis of Petroleum 263
The Petroleum of Galicia 264
Petroleum in Venezuela 265
The Use of Petroleum in Boiler Furnaces 265
Liquid Fuel in the Manufacture of Iron 265
Petroleum Refuse as Fuel 266
An Oil Fired Forge 267

VI.—NATURAL GAS.

Natural Gas in China 267
Natural Gas in Indiana 267
Natural Gas in Meade County, Kentucky 268
Natural Gas in Iron-making 269

VII.—ARTIFICIAL GAS.

The Ingham Gas-Producer 270
Recent Improvements in the Production of Water Gas . . . 271
The Use of Water Gas 272
The Lomas Water Gas Plant 272

VIII.—COAL MINING.

Improvements in Mining Appliances 272
Application of Electricity to Mining 273
A New Coal-Boring Machine 274
Refilling Collieries 274
Goaf Stowing 274
Winding from Shafts 274
Remarkable Mine Output 275
Signalling from Mining Cages 276
Electric Haulage 276
Movable Platform for Inclined Planes in Mines 277
Timbering in Mines 277
Rapid Driving of a Cross-Cut 277
Pumping Engine at the Bernissart Colliery 278
Electric Lighting at the Ynishir Colliery 278
Electric Lighting in Mines 279
Safety Lamps 279
Ventilation of Mines 279
Theory of Centrifugal Ventilators 280
The Air of Coal Mines 281
The Prevention of Colliery Fires 281
A Fire-Damp Meter 282

PAGE

Employment of Explosives in Fiery Mines 282
Trials of Explosives 284
Bellite 285
Dahmen Safety Dynamite 286
Emmensite 287
Dynamite and Safety Cartridges 287
Hengst Powder 288
Roburite 288
Securite 289
Blasting 289
Various Methods of Firing Shots 289
Premature Explosions of Gunpowder 290
Air-Compressing Machinery at Collieries 291
Measurement of Earth Pressure in Mines 291
Plotting Colliery Surveys 292

PRODUCTION OF PIG IRON.

I.—BLAST FURNACE PRACTICE.

The Feasibility of Using Cheaper Fuels in Blast Furnaces . . . 294
Anthracite and Coke in the Blast Furnace 295
Fine Magnetites in the Blast Furnace 299
Magnetite Ores and Foundry Iron 300
Blast Furnaces at Mont St. Martin 304
Blast Furnaces in the Ural 304
An American Charcoal Blast Furnace 305
Record of a Charcoal Blast Furnace 305
Blasting Large Masses of Iron and Steel 305
Important Repairs to a Furnace in Full Blast 306
Blast Furnace Gases 306
American Blast Furnace Practice 308
The Ensley Blast Furnaces, Alabama 309
The Keystone Ironworks 309
The Riverside Ironworks 309
Hot Blast Stoves 310
Hollow Pig Patterns 311
The Grading of Pig Iron 311
Chrome Ferro-Manganese 311
The Cost of Pig Iron 312
The Cost of a Ton of Pig Iron in the Sequachee Valley . . . 313

II.—CHEMICAL COMPOSITION OF PIG IRON.

Composition of Ferro-Manganese and Ferro-Silicon . . . 314
Composition of American Pig Iron 315

III.—BLAST FURNACE SLAGS.

PAGE
GEHLENITE IN SLAG 315
SLAG BRICKS 315
SLAG PAVING-STONES 316

IV.—FOUNDRY PRACTICE.

COMPRESSED AIR FOR BLAST IN CUPOLA FURNACES 316
FERRO-SILICON AND THE ECONOMY OF ITS USE 317
EXAMINATION OF CAST IRON 323
CAST IRON PIPES 323
THE COST OF MAKING WHEELS 323

PRODUCTION OF MALLEABLE IRON.

THE HUSGAFVEL DIRECT REDUCTION PROCESS 325
FORSBERG'S HEARTH 328
THE BLAIR DIRECT REDUCTION PROCESS 328
IRON-MAKING IN MADAGASCAR 329
IRON-MAKING IN COREA 330

FORGE AND MILL MACHINERY.

A NEW FORGING MACHINE 331
NEW POWER PRESSES 331
A NEW DRAWING PRESS 331
THE MASON INGOT MANIPULATOR 331
A THREE-THOUSAND-TON SHEAR 332
A FORTY-TON SHEAR 332
A NEW VERTICAL MILLING MACHINE 333
THE ROLLING MILLS OF THE GRAZ SOUTHERN RAILWAY 333
A NEW RAIL TRAIN AT THE EDGAR-THOMSON STEELWORKS . . . 334
UNIVERSAL MILLING MACHINES 334
ROLLING MILLS AT PITTSBURGH 335
THE UNIVERSAL MILL AT THE HOMESTEAD STEELWORKS 335
THE ROLLING MILL AT THE HOMESTEAD STEELWORKS 335
HORIZONTAL BORING MILL 337
A RADIAL DRILLING MACHINE 337
A TURNING AND BORING LATHE 337

PRODUCTION OF STEEL.

I.—THE CARBURISATION OF MALLEABLE IRON.

PAGE

A New Crucible Steel Blast at Chicago 339
Manufacturing Steel from Wrought Iron 339

II.—THE OPEN-HEARTH PROCESS.

Chrome Iron Ore Linings in Open-Hearth Furnaces . . . 340
The Batho Furnace 341
The Basic Open-Hearth Process 341
The Basic Steelworks of the Graz Southern Railway . . . 342
Styrian Open-Hearth Steel 343
The Open-Hearth Plant at the Homestead Steelworks, Pittsburgh . 343
The Pencoyd Steelworks, Pennsylvania 344
The Henderson Heating Furnace 344
A New Gas Valve 345

III.—THE BESSEMER PROCESS.

The Krupp Steelworks at Essen 345
The Wheeling Steelworks 346
Blowing Engines for Steelworks 347
Dephosphorised Steel 348
Basic Slag as a Manure 349
A Pulveriser for Basic Slag 350
Comparison of Basic Slag and Superphosphate 351

FURTHER TREATMENT OF IRON AND STEEL.

The Williams Process of Making Solid Ingots 352
Tool Steel 352
Damascus Steel 353
Variations in the Thickness of Steel Plates 354
Ferro-Manganese 354
Ferro-Aluminium 354
The Protection of Iron from Rust 355
Corrosion of Iron and Steel 355
Electric Welding 356
Pipe-Cutting and Threading Machinery 357
Rolling Wire 357
Wire and Wire Ropes 357
A Long Wire Rope 357
Nails of Tinned Sheet Iron 358

PAGE

Rails 358
Life of Rails 361
A New Steel Sleeper 362
Iron Ties and Sleepers 362
The Standard Metal Cross Tie 362
The Cost of the Production of Steel Rails 363
Guns 363
Armour Plate Trials 364
Armour Trials 364
Bridge Steel 364
The Use of Ingot Iron for Bridges 365
Steel for Shipbuilding 366
Cast Steel Water Jackets 366

PHYSICAL PROPERTIES.

Magnetisation of Iron at High Temperatures 368
Magnetisation of Iron in a very Strong Field 368
The Volatility and Mobility of Iron Atoms 368
Crystallisation of Iron 371
Iron Fibre 371
The Microscopic Examination of Iron 371
Spectroscopy 372
Steel and its Uses 373
Strength of Wire 374
File Steel 374
Weak Spots in Ingot Iron Test Pieces 375
Behaviour of Tempered Steel 376
Chrome Steel 376
Fractures of Steel Ingots and Rails 377
Tests of Rivet Steel 377
Tests of Steel Eye-Bars 378
Tests for Proving Bayonets and Swords 378
Iron for Building Purposes 379
Recent Testing Machines 379
Regulations for the Delivery of Iron and Steel 381
The Nomenclature of Iron and Steel 381

CHEMICAL PROPERTIES.

The Nitrogen Contained in Ingot Iron 383
Occlusion of Gases on Iron 385
The Influence of Oxygen on Iron 385
Carbon in Iron 386

PAGE
Action of Hydrochloric Acid on Cast Iron 390
Rusting of Ironwork in Tunnels 390
The Chemical Composition of Steel Rails 390

CHEMICAL ANALYSIS.

I.—ANALYSIS OF IRON AND STEEL.

International Standards for the Analysis of Iron and Steel . . 391
Determination of Carbon in Iron 393
Influence of Sulphur on Eggertz's Carbon Colour Tests . . . 394
The Determination of Manganese 394
The Determination of Phosphorus 395
The Influence of Arsenic on the Determination of Phosphorus . . 396
The Determination of Sulphur 396
The Determination of Silicon in Ferro-Silicon 397
The Volumetric Determination of Chromium 398

II.—ANALYSIS OF IRON ORES AND SLAG.

The Electrolytic Method as Applied to Iron 400
The Determination of Iron 400
The Influence of Copper on the Determination of Iron . . . 401
An Ore Pulverising Mill 401

III.—FUEL ANALYSIS.

The Determination of Sulphur in Coal 401

IV.—GAS ANALYSIS.

Gas Testing and Sampling 401

STATISTICS.

I.—UNITED KINGDOM.

Mineral Statistics 403
Iron Trade Statistics 403
Imports and Exports 404
Iron Ore Supplies 405
The Coal Question 406

II.—AUSTRALASIA.

PAGE
MINERAL STATISTICS OF NEW SOUTH WALES 407
MINERAL STATISTICS OF NEW ZEALAND 407

III.—AUSTRIA-HUNGARY.

MINERAL STATISTICS 407
METALLURGICAL STATISTICS OF BOHEMIA 408
PRODUCTION OF PETROLEUM 408
THE PETROLEUM INDUSTRY OF GALICIA 409
ACCIDENTS IN MINES 409
IRON TRADE STATISTICS OF HUNGARY 410
THE IRON INDUSTRY OF UPPER HUNGARY 411

IV.—BELGIUM.

IRON TRADE STATISTICS 412
IMPORTS AND EXPORTS 412
THE COAL INDUSTRY OF BELGIUM 413

V.—CANADA.

MINERAL STATISTICS 414

VI.—CHINA.

MINERAL RESOURCES OF CHINA 414

VII.—CUBA.

MINING INDUSTRY OF CUBA 415
MANGANESE MINES IN CUBA 415

VIII.—FRANCE.

IRON TRADE STATISTICS 416

IX.—GERMANY.

IRON TRADE STATISTICS OF GERMANY 417
PIG IRON PRODUCTION 420
IMPORTS AND EXPORTS 420
THE IRON INDUSTRY OF UPPER SILESIA 420
IRON TRADE STATISTICS OF LORRAINE 421

X.—JAPAN.

PAGE
IMPORTS OF RAILS 422
COAL IN JAPAN 422

XI.—RUSSIA.

MINERAL STATISTICS 422
MANGANESE ORE IN TRANSCAUCASIA 422
COAL IN RUSSIA 423
COAL IMPORTS 423
EXPORTS OF PETROLEUM 423

XII.—SPAIN.

MINERAL STATISTICS 424
IRON INDUSTRY OF BILBAO 424

XIII.—SWEDEN.

IRON TRADE STATISTICS 425
IRON EXPORTS 426
PRODUCTION OF OPEN-HEARTH STEEL 427

XIV.—UNITED STATES.

THE AMERICAN IRON TRADE 427
IMPORTS AND EXPORTS 429
FURNACES IN BLAST 429
PRODUCTION OF COAL 431
LAKE SUPERIOR IRON ORE MINES 431
EXPORTS OF PETROLEUM 432
THE IRON INDUSTRY OF THE SOUTHERN UNITED STATES 432
THE BIRMINGHAM DISTRICT, ALABAMA 433
THE IRON INDUSTRY OF THE WESTERN UNITED STATES 433
THE COST OF BLOOMS AND BILLETS 434

BIBLIOGRAPHY.

METALLURGY 436
MINING 436

LIST OF PLATES.

JOURNAL No. I.—1889.

		NO. OF PLATES
To Illustrate the President's Address,		12
„	Mr. Gautier's Paper on "The Thomasset Testing Machine,"	4
„	Mr. J. H. Wicksteed's Remarks on "The Thomasset Testing Machine,"	1
„	Mr. H. Sack's Paper on "Universal Rolling Mills,"	1

PROCEEDINGS

OF THE

IRON AND STEEL INSTITUTE.

ANNUAL MEETING, 1889.

WEDNESDAY, MAY 8TH.

THE Proceedings of the INSTITUTE were opened this morning at the Institution of Civil Engineers, Great George Street, London—D. ADAMSON, Esq., President, in the chair.

The Minutes of the previous Meeting were read, approved, and signed by the President.

NEW MEMBERS.

Messrs. ARTHUR COOPER and J. J. RICHARDS were nominated as scrutineers, and reported, on the completion of their scrutiny, that the following candidates had been duly elected as members of the Institute:—

ADLER, HARMER.....Chicago, U.S.A.
ANDERSON, ALEXANDER.....Royal Arsenal, Woolwich.
ARMSTRONG, G. F., M.A., F.R.S.E.....The University, Edinburgh.
BANISTER, HERBERT.....London Bridge Station, London.
BARNS, GEO. T.....Crane Iron Co., Philadelphia.
BEARDSHAW, WM. FREDERICK.....Baltic Steelworks, Sheffield.
BLEICKERT, ADOLF.....Leipzig, Germany.
BRABY, CYRUS.....110 Cannon Street, E.C.
BREMME, FRIEDRICH GUSTAV THEODOR..Julienhütte, Germany.
BROWNE, JOHN.....Portugalete, Spain.

BUTLER, THEOBALD FITZWALTER.....Ulverston.
CHADWICK, DAVID.....36 Coleman Street, London.
DANIELSSON, CARL L.....Bofors Steelworks, Sweden.
DICKINSON, EDWARD.....Meersbrook Bank, Sheffield.
ELLIS, ARTHUR STANLEY.....New Glasgow, Nova Scotia.
EVRARD, ALFRED.....19 Boulevard des Italiens, Paris.
FERGUSON, CHAS. WM.....4 Buchanan Street, Glasgow.
GARRISON, F. LYNWOOD.....Philadelphia, U.S.A.
HAGGIE, PETER SINCLAIR.....Gateshead-on-Tyne.
HENNING, GUSTAVUS.....Stamford, Conn., U.S.A.
HOLLINGWORTH, JAMES.....Dobcross, Oldham.
HUTCHINSON, WM.....Staffordshire Steel Co., Bilston.
JAMES, ENOCH.....Rhymney.
JAMIESON, JAMES FLEMING FYFE.....9 Queen's Gate, London, S.W.
JORDAN, ANDREW JACKSON.....68 and 70 Baker's Hill, Sheffield.
KORLE, FRIDDLIN.....29 Spring Hill Road, Sheffield.
LEES, SAMUEL.....Ashton-under-Lyne.
LIDDELOW, CHARLES.....Carlisle.
MACDONALD, KENNETH.....Rose Hill, Whitehaven.
MALLABAND, JOHN.....Pitsmoor, Sheffield.
MATHESON, EWING.....Farnley Ironworks, near Leeds.
M'CREATH, ANDREW S.....Harrisburg, Pennsylvania.
MILLWARD, GEORGE ANTHONY.....41 Church Hill, Wednesbury.
MILWAREL, GEORGE A.....Wednesbury.
MOSES, EDMUND BAMFORD.....Cwm Avon, Glamorgan.
MUIR, SIR WILLIAM, K.C.S.I., D.C.L.....The University, Edinburgh.
NICHOLSON, JAMES PERCIVAL.....Bowling Ironworks, Bradford.
OAKES, GERARD R.....Riddings, Alfreton.
PETERS, THEODOR.....Berlin, 14 Wichmannstrasse.
RANSOME, ROBERT JAMES.....Water-Side Works, Ipswich.
RICHARDS, DAVID.....Ammanford, Carmarthen.
ROGNETTA, F. B., COLONEL.....Terni, Italy.
SEEHOFF, ROBERT.....Witten, Westphalia.
SPARROW, HENRY.....Himley, Dudley.
SPENCER, CHARLES.....Stockton-on-Tees.
STROUDLEY, WILLIAM.....Brighton.
TOMPKIN, JOHN BENJAMIN.....Newhall Steelworks, Sheffield.
WALTON, JOSEPH PEARSON.....Campbell Street, Wishaw, N.B.
WATT, JOHN LAUDALE WILSON.....3 Dennistown, Glasgow.
WILLIAMS, JAMES.....The Fields, Newport, Mon.
WOOD, STUART.....Philadelphia, U.S.A.
WOODWARD, WM. C.....Biddulph Valley Ironworks, Stoke-on-Trent.
WOOLCOCK, HENRY.....Whitehaven.
ZABALBURN, RAMON DE JAUREGUI Y.....Bilbao, Spain.

REPORT OF COUNCIL FOR THE YEAR 1888.

The GENERAL SECRETARY read the following REPORT of the Council for the year 1888:—

SINCE the Council submitted its last annual Report to the members, the Iron and Steel Institute has completed the twentieth year of its existence. Its career during that period has been one of prosperity and usefulness, upon which the members may fairly be congratulated.

The number of members on the list of the Institute at the end of 1888 was 1355, which is a net increase of 42 on the number at 31st December 1887, after all deaths and withdrawals have been allowed for. The total number of members elected during 1888 was 94, so that 52 names were removed from the register in the same period, 25 in consequence of death, and 27 from other causes. Fifty-four names are proposed for election at the present meeting.

The following members have been removed from the list by death during the year 1888:—

William Adams, Cardiff.
E. W. Baumler, Vienna.
Edward M. Bell, Coatbridge.
C. J. Brock, London.
John Brown, Birmingham.
Stephen Burridge, Sheffield.
Henry Cadell, Bo'ness, N.B.
Mark W. Carr, London.
Thomas R. Crampton, London.
F. C. Guilliaume, Cologne.
Robert Hadfield, Sheffield.
Peter Haggie, Gateshead.
Thomas E. Harrison, Sunderland.
Alfred Hodgetts, Carnforth.
J. H. J. Kam, Delfshaven, Holland.
Charles Markham, Chesterfield.
John Maylor, Chester.
David Nurse, Redbrook.
H. Robertson, London.
John P. Roe, Consett.
Hy. Wm. Schneider, Barrow-in-Furness.
Henry Smith, Spennymoor.
John Waddell, Edinburgh.
J. R. Waddle, Llanelly, S. Wales.
Ybarra, F. L. de, Bilbao, Spain.

Two changes have occurred in the Council during 1888. Mr. William Jenkins of Consett has been elected a vice-President in the place of the late Mr. Charles Markham, and Mr. J. D. Ellis of Sheffield has been elected an ordinary member of Council in the room of Mr. Jenkins.

During the year 1888 there have been, as usual, two general meetings of the Institute—the Annual Meeting, held in London, and the

Autumn Meeting, held in Edinburgh. At these meetings the following papers were read and discussed :—

At the Annual Meeting in London.

On the Mutual Action of Sulphur and Silicon on Iron at High Temperatures. By Mr. T. TURNER, Mason Science College, Birmingham.

On the Use of Water-Gas for Metallurgical Purposes. By Mr. A. WILSON, Stafford.

On an Imperfection in Mild Steel Plates, considered Chemically. By Mr. H. ECCLES, Port Talbot.

On the Mechanical Apparatus for Continuous Moulding at the Works of M. Godin, Guise. By Mr. JAMES JOHNSTON, Manchester.

On the Effect of Arsenic on Mild Steel. By Mr. F. W. HARBORD and Mr. A. E. TUCKER, Bilston.

On the Manufacture of Ordnance at Trubia. By Major CUBILLO, Trubia.

On the Melting of Wrought Iron or Steel Scrap, mixed with Ferro-silicon, in Cupola Furnaces. By Mr. F. GAUTIER, Paris.

On the Behaviour of Arsenic in Ores and Metals during Smelting and Purification Processes. By Mr. JOHN PATTINSON, Newcastle-upon-Tyne, and Mr. J. E. STEAD, Middlesbrough.

On a New Instrument for the Measurement of Colour, more especially as Applied to the Estimation of Carbon in Steel. By Mr. H. LE NEVE FOSTER, West Hartlepool.

At the Autumn Meeting in Edinburgh.

On a Horizontal Compound Lever Testing Machine of 15,000 powers, with further Recording Lever of 150,000 powers. By the PRESIDENT.

On Manganese Steel. By Mr. R. A. HADFIELD, Sheffield.

On the Mining and Metallurgical Exhibits at the Glasgow Exhibition. By Mr. W. J. MILLAR, C.E., Glasgow.

On the Forth Bridge. By Mr. F. E. COOPER, M.I.C.E., Resident Engineer.

On the Chemical Processes Involved in the Rusting of Iron. By Professor CRUM BROWN, F.R.S.S.L. and E., Edinburgh.

On a New Form of Air Pyrometer. By Professor WIBORGH, Stockholm.

The Council decided to hold the Autumn Meeting in the United Kingdom, instead of meeting in the United States, as was at one time

intended. Edinburgh was selected as the place of meeting, chiefly on account of its proximity to the International Exhibition that was in progress in the city of Glasgow. The University authorities afforded facilities for holding the meetings within the walls of the University, and the Principal and the chief professors of the University assisted in the arrangements for the meeting, which passed off successfully. Excursions were made to the Forth Bridge, to the Glasgow International Exhibition, to the Marquis of Lothian's and other collieries in the neighbourhood, to the oil-works at Broxburn, and to other places of interest in Edinburgh and its vicinity. The Lord Provost and Corporation of Edinburgh gave a reception and coversazione in honour of the Institute, and at Glasgow the proceedings of the week terminated with a luncheon, given by the Local Reception Committee formed in that city for the purpose of receiving and entertaining the Institute.

An invitation from the French Society of Civil Engineers—communicated through M. Pourcel—to hold the next Autumn Meeting of the Institute in Paris, has been accepted by the Council, and it has been decided that the meeting will commence on Tuesday, the 24th day of September next, and will extend over several days. A Committee of Members of the French Society of Civil Engineers has been formed for the purpose of receiving and entertaining the Institute at Paris on that occasion, and Mr. Henry Chapman has again kindly undertaken the duties of Honorary Local Secretary. Arrangements are being made with a view to enabling the members to visit Le Creusot and other leading iron and steel works in France, and M. Eiffel, the designer of the Eiffel Tower, will receive the members on behalf of the French Society of Civil Engineers, of which he is the President.

The difficulties which lay in the way of holding the Autumn Meeting of the Institute for 1887 in the United States having been removed, and an intimation having been received that it would be most agreeable to our colleagues in that country that the Institute should arrange for an American meeting at an early date, the Council have accepted a cordial invitation from the American Institute of Mining Engineers to hold the Autumn Meeting of 1890 on American soil. Due notice will be given of the arrangements proposed for the meeting in the United States, and members will shortly be asked to notify whether they intend to take part therein. The Council hope that no time will be lost on the part of members in making up their minds on this matter, and that the number of acceptances will be sufficient to justify the very considerable amount of anxiety and trouble which such a meeting must

necessarily occasion on the part of those who are to be our hosts. Mr. Andrew Carnegie, one of our own members, who is well known on both sides of the Atlantic, has been elected chairman of the committee which will receive us in the States, an appointment which will go far to ensure a reception worthy of the occasion.

The Council have had under consideration the subject of the entertainment which has usually been provided for the members at the Autumn Meetings of the Institute, and have adopted a resolution which is intended to discourage the continued expenditure at our Autumn Meetings of considerable sums in providing free luncheons and other forms of entertainment, which are really in no way essential to the success or enjoyment of these *réunions*. The experiment which was made at Edinburgh in August last, of having the luncheons provided and paid for by the members themselves, was so entirely satisfactory, that the Council would prefer to see this practice established as a rule, and they feel confident that if this were done, the Institute would be none the less welcome in some localities that would probably be pleased to receive us but for the financial strain which, while the Institute was of smaller dimension, they could probably see their way to undertake, but which has now become really onerous, if not burdensome, in certain smaller localities that are well worthy of a visit.

Since the date of our last annual meeting the Council has been invited to co-operate in the work of the Imperial Institute, with which it is now very closely identified, having H.R.H. the Prince of Wales, President of the Imperial Institute, as its latest honorary member; Sir Lowthian Bell, Bart., Past President, as the Vice-Chairman of Council; and Sir Frederick Abel, C.B., F.R.S., one of our Council, as its Secretary. The Council think they are entitled to regard the selection by H.R.H. the Prince of Wales of Sir Lowthian Bell to fill the office of Vice-Chairman of Council as a high compliment to the important part which Sir Lowthian has taken in connection with the work of this Institute, and kindred labours. Your Institute was represented at a Conference called by the Executive of the Imperial Institute in October last for the purpose of organising a department of intelligence in connection with different branches of industry, &c., and establishing a system of correspondence for those objects. The Council has resolved to co-operate as far as they can in the promotion of this useful work.

Having ascertained that a considerable number of American metallurgists and engineers proposed to visit England this summer, *en*

route to the Paris Exhibition, your Council took steps to ascertain whether they could take any, and, if so, what steps, in order to make the excursion of their American colleagues as agreeable as possible while they were on English soil. The leading arrangements necessary for this purpose have been undertaken by the Institution of Civil Engineers, the senior society representing applied science, but on the special committee formed by that Institution, in view of the excursion in question, your Council is well represented, and opportunity will also be afforded your Council and members for the exercise of private hospitality. The excursion has been so timed that it could not, unfortunately, be made to coincide with the Annual Meeting of the Institute, the party expecting to arrive in Liverpool about the 3rd of June.

The statement of accounts prepared and certified by the honorary treasurer (Mr. David Dale), was issued to the members of the Institute in advance of the Annual Meeting, as usual. The Council refer with satisfaction to the fact that the income for 1888 has been nearly £200 in excess of that of the previous year, while the expenditure has been £172 less. The balance on the year amounts to £792.

The retiring Members of Council for 1889, as announced at the Edinburgh Meeting, are:—

Vice-Presidents.

Sir J. G. N. Alleyne, Bart. Mr. Robert Heath.
Mr. E. Fisher Smith.

Members of Council.

Mr. W. H. Bleckly. Mr. T. E. Horton.
Mr. P. C. Gilchrist. Mr. Wm. Whitwall.

In the absence of other nominations, these gentlemen will be re-elected.

The PRESIDENT said, as that would be his last official duty, he was very glad to state that the Institute continued in a prosperous condition. The record of the papers which had been read thoroughly established the fact that the past year had been one of usefulness. If they could to some extent increase the number of

their members, it appeared to him that they would soon reach the point at which the annual income would exceed the expenditure by £1000; and when that was accomplished he hoped that the Council, whoever they might be, would take into consideration the propriety of working in conjunction with some other learned Societies with a view to getting a home of their own. But even should they fail in that effort, at any rate the interests of the Institute would be advanced by an increase of the number of members. Having anxiously looked at the progress of the Institute for many years, he had come to the conclusion that there was no duty connected with it, in its official character, that was more important than that of bringing in, if possible, the small ironfounders connected with the great distributing trade of the country, and giving them a better technical knowledge of what a piece of cast iron was. Great service had been rendered to the ironfounders and constructive engineers of the Institute, inasmuch as they were now fairly acquainted with the alloys that constitute what was called a good foundry metal or good forging steel, by the Bessemer or the basic process. He might mention, as an encouragement to others acting in a similar capacity, that since he took a special interest in studying the alloys connected with cast iron he had come to the conclusion that he had saved 80 per cent. of the waste that was previously lost in his foundry, and that all the castings manufactured there were now of greater value than they were before. The practical outcome of all the knowledge that was important to the Institute, in his opinion, established the great truth that it was not a question where cast iron was made, or what particular purpose it was made for; but they wanted to know what alloying compound was suitable for every good special class of work. To make iron in stock, and to store it in Glasgow, Middlesbrough, and other places, was a sad mistake in commercial business, because any of those brands could be imitated in other districts, and a useful pig iron for all practical purposes might be made without having to depend on any given manufacturing section. The Institute had therefore rendered good service to the iron trade in this matter, and he believed it would continue to do so.

He congratulated all connected with the Institute that they had this year so far seen a much better trade. A better prospect

appeared to be before them, and he trusted that at the end of the year the members generally would find their balance sheets more satisfactory than they had been. The report of the Institute as a whole was more favourable, and as the statement of accounts showed a balance of £792 to be carried forward, he thought that fact would be regarded as eminently satisfactory. He had great pleasure in proposing "That the Report of the Council and the Statement of Accounts for the year 1888 be adopted." He would ask some gentleman who was not on the Council to second the proposition. It was not necessary that he should say anything further as to what had been done; he would leave the members to judge how far the Council had merited their approval.

MR. EDWARD H. CARBUTT said that, as an outside member and a member of a kindred Institution, he had great pleasure in seconding the adoption of the report. The only thing that struck him was, that it was too modest. The Council had done a great deal of useful work for the benefit of the iron trade, and had not taken sufficient credit for it. The Institute had been established twenty years, and if they looked at the list of past-Presidents, Vice-Presidents, and members of Council, they would come to the conclusion that they had had the leading men in the iron, steel, and kindred trades representing them on the Council. Those gentlemen had done a large amount of work for the benefit of the mother-country and of the whole world. With men of the calibre of those on the Council, working together for the benefit of the iron and steel manufacture, they could not help improving the trade of the country. Mr. Adamson had stated, what he believed had also been mentioned before by Sir Lowthian Bell, that they had now come to the conclusion that, no matter where the iron ore came from, if they could only eliminate its bad qualities, either by chemical or mechanical means, the resultant material was the same as if made from pure ore, thus making our large deposits of inferior ore available. That result had been brought about mainly by the Iron and Steel Institute, and therefore he believed that the country as a whole was greatly indebted to it. Having been connected with the Institution of Mechanical Engineers, many of the members of which were also members of the

Iron and Steel Institute, he was delighted to find that the latter Society was making such progress, and he would re-echo what Mr. Adamson had said, that if at any time the Institute thought of building a house, the Institution of Mechanical Engineers would, he was quite sure, be very glad to join them. One of the reasons why the Institute had got on so well was, that it had been liberal in the admission of members. It had not acted in any narrow-minded spirit as to whether this or that man should be a member, but had received men who were willing to come and give the Institute the benefit of what little experience they might have, allowing every man, whether a small or a large ironmaster, to have his say. He believed that no Institution had done better work, and entertaining that view, and congratulating the Institute upon having elected such a good President as his old friend Sir James Kitson, he begged heartily to second the adoption of the Report.

The motion having been unanimously adopted,

Mr. THOMAS WRIGHTSON (Stockton-on-Tees) said he had been asked at short notice to propose—

"That the best thanks of the members of the Iron and Steel Institute be and are hereby tendered to the President, the Council, and the Treasurer, for their services during the past year."

It must be a source of regret to every member of the Institute to have to say farewell to Mr. Adamson, for the manner in which he had conducted the business of the Institute during the past two years had been in every way satisfactory. At the same time, they had the gratification of knowing that they would still have the benefit of his presence at their future meetings, and he was quite sure that he would support the new President, Sir James Kitson (whom they all welcomed with great heartiness), to the best of his power. They also thanked the Council for the way in which they had fulfilled their duties. The success of the Institute had largely depended on the labours of the gentlemen who had been selected as members of the Council. They had among them men who were known throughout the world for their connection with the iron and steel trades. They had also on the Council men who were connected with other Institutions, and through their agency

ıe believed the influence of the Institute was extending rapidly in the country. They had further to recognise the services of their Treasurer, Mr. Dale, who did his work so thoroughly well. Although he did not appear very prominently before them, he was sure that Mr. Dale's labours were properly appreciated by the whole of the members.

Mr. W. G. AINSLIE, M.P., said he had much pleasure in seconding the resolution, but after the remarks of the proposer it was unnecessary that he should add anything.

The motion was unanimously adopted.

The PRESIDENT said he had much pleasure in acknowledging the resolution which had just been so pleasantly received and so unanimously supported by the members present. If there was one thing which was more satisfactory to the Council than another, it was to receive an unanimous vote of confidence. When the Institute was established by the leading members of the iron and steel trades it was very much wanted; and if it had not been established, the knowledge required to guide the iron and steel manufacturers, not only of England, but of every other country, would have been very much less than that which they now possessed. As a body, they had been anxious to show their strength and their authority in the manufacture of articles of which a heavy output was required. He did not say that that was always commercially advantageous. But if he had any authority to recommend a different course, he would say to the members, let them aim at high excellence, at the best possible quality of manufacture, and get the best possible price for all their productions. That there was a great range was manifest to every one. Since the formation of the Institute steel rails had been produced at an increasingly small cost, until they were now quoted at a less price than the old iron rails of South Wales and Middlesbrough, and he thought it was a most fortunate thing for the country that it was no longer necessary or desirable to use that material for the great transport operations of the country. He had sometimes amused himself by looking in the opposite direction, and asking if there was anything

that would lead them to aim at manufacturing a very much higher class of articles than rails, tires, or ship-plates. To go to the further extreme, he had looked into the question of the cost of steel when worked up into hair-springs of the most delicate character for watches, and he had found that, instead of costing £4, 10s. per ton, the commercial wholesale price of such hair-springs was £43,040,000. He had got the price paid by a wholesale buyer, and had tested it in several different ways, so that the figures might be depended upon. Even the watch main-springs had a value that was surprising and almost fabulous. These, however, were exceptional articles, at the opposite end of the commercial list to common steel rails or ingots. But there were some hundreds of articles intermediate between the steel rail and the hair-spring, which were of much greater value than the heavy articles to which he had referred; and it was in that direction that they could look for maintaining their reputation for high-class work, and reducing competition by a specialty of manufacture as far as practicable. He commended to their notice those few remarks, which were the last he would have to make in his official capacity. If they could successfully extend the commercial operations of the members, it would be a great gain to the Institute itself.

As far as the past two years were concerned, he had only to thank the Council for their individual and united support, and all the members for their loyal co-operation during his Presidency. He felt convinced that if any member occupying the Presidential chair of the Institute acted as a just umpire in giving his decisions, he would receive from the majority of the members all the support and encouragement that he had himself received. He trusted that Sir James Kitson, who was about to occupy the chair, would receive the same support during his period of office as had been extended to himself under the same circumstances, and then he had no doubt that at the end of his Presidency the Institute would be equally prosperous and progressive. He now begged to call to the chair his successor, Sir James Kitson.

Sir JAMES KITSON, Bart., then assumed the chair, and delivered the following address:—

PRESIDENT'S ADDRESS.

I RECOGNISE that it is a great distinction to be permitted by your favour, and by the consideration of the Council, to undertake the duties of the President of the Iron and Steel Institute in succession to Mr. Adamson, who has so assiduously and so successfully presided over the Institute for the past two years.

The proposal that I should occupy this chair was made to me in so kind a manner, and was accompanied by assurances of support from the past President, as well as from others qualified to advise and assist me in matters concerning the repute and the efficiency of this Institute, that I have ventured to take the office, knowing that from all of you, in the interests of the Institute, I shall receive hearty support and generous consideration.

In view of our anticipated visit to France in September next, and our probable expedition to the United States of America in the autumn of next year, I shall need much of your help.

While disclaiming any pretensions, permit me to say that I have had a training and perceptions which have enabled me at least to recognise the value and the necessity of the application of the widest knowledge of the principles of science to the manufacture of iron and steel.

Whatever progress the works under my direction have made has been materially advanced by the careful attention which I and those who work with me have given to the information which scientific and practical men, through this Institute, have openly and generously offered for the service of all.

I am only therefore endeavouring to discharge a debt by taking this duty.

Our past President, Mr. Adamson, told me that I should consider myself as placed here as representing to some extent an old-established branch of the iron trade of high repute, namely, the manufacture of best Yorkshire iron, with which it has been my fortune for many years to be associated.

My Conservative tendencies may not be considered a disqualification for the representation of conservative methods of manu-

facturing iron, having regard to the fact of my alliance with more advanced principles, like those applied in the manufacture of steel.

It will be remembered that at the Paris meeting in 1878, Mr. Adamson contributed his valuable paper on the Mechanical and other Properties of Iron and Mild Steel. In the discussion which followed, some eager converts predicted the rapid decline and speedy extinction of the use and manufacture of wrought iron, but I ventured to bring forward evidence of the treacherous nature of steel in the *then* existing state of general knowledge of its manufacture, and of the methods of its treatment. I pointed out the need of care and prudence in the adoption of steel.

For best Yorkshire iron I stated that it would be wise and prudent to exercise great caution in ceasing to use it for many special and responsible purposes for which it was employed.

I gave my opinion that ample time would be afforded for iron-makers to prepare themselves for the predicted changes, and especially that a material like best Yorkshire iron, whose properties enable it to endure without deterioration so much punishment in the hands of the smith and engineer, would for many years to come find a trusted place in the workshops of the world.

Since I ventured this prediction ten years have passed, but the works I direct have no fewer puddling furnaces to-day than they had at that moment, and to-day every one of those puddling furnaces is in full work.

There is undoubtedly a revival in the demand for wrought iron. The explanation, no doubt, is that with the enormous expansion of the purposes to which steel is applied, there has followed a multiplication of the many special purposes for which iron is needed. So that iron manufacturers can regard with satisfaction and hope the expansion of the use of steel, and the existing volume of consumption may long be maintained.

Iron made by the works in West Yorkshire, of which the widest known is Low Moor,* owes its reputation to its uniform and regular quality.

The properties which are its attributes are due in some measure to the purity of the fuel used in its manufacture, but also, in my opinion, in large measure to the minute and rigid care with which its manufacture is conducted.

* Low Moor, Bowling, Farnley, Monkbridge, Taylor Brothers & Co.

Excessive care is taken to examine and select the puddled iron, to heat all iron well, to heat and hammer it repeatedly to secure sound blooms, and to put a large amount of work upon the iron.

The final testing and works-inspection is rigid and conscientious.

The pig iron produced in West Yorkshire for best iron purposes is still exclusively made with cold blast.

Best Yorkshire iron is distinguished by the property described by the practical man as that of standing fire well. Bars and plates in the hands of the smith will bear repeated heating, drawing, and flanging without deterioration, and the special methods and appliances required in the treatment of steel are not needed in dealing with best iron.

Hence there are everywhere workshops in which best Yorkshire iron is, and will long continue to be, in demand. The ductility, the high but not excessive tensile strength, the uniformity and reliability of best Yorkshire iron have secured the confidence of engineers. It was but yesterday the practice of the majority of locomotive engineers to specify that no other material should be used in the construction of boilers, engine axles, links, and coupling chains. The furnaces of all boilers in Her Majesty's ships and in the mercantile marine were made of best Yorkshire iron. For chains where life and limb are risked there is still no material to which it is as safe to trust.

Yorkshire plates will support a tensile strain of 22 tons on the square inch, with an elongation of 16 per cent. lengthways, and 20 tons tensile strength crossways, with an elongation of 10 per cent., and Yorkshire bars 24 tons, with an elongation of 25 per cent.

Best iron can be made by special methods to support a higher tensile strain, but it will be harder, and it follows that it is not as weldable, hence it will not endure as much heating in the smith's fire, or the severe treatment or amount of work which the regular Yorkshire quality would bear.

The additional tensile strength is gained at the expense of the ductility and the general soundness of constitution, properties which have justified the confidence of engineers for the last half century. It does not seem prudent to force conditions which a material of ascertained reliability does not afford cheerfully and without risk.

It would be easy to give you a long catalogue of the work done and the services rendered by best Yorkshire iron, but I will not take too great an advantage of my position. As an example of faith and confidence I may quote the experience of Sir W. T. Lewis and Sir George Elliott, who, on visiting a mine in Nova Scotia, had to descend an incline of 1200 yards in length, the steepest they had ever seen. They were asked to place themselves on a heavily-loaded platform. Sir W. T. Lewis began to examine and calculate the strength of the chains, when the engineer told him not to trouble, as all the iron was from Low Moor, and they had never had a breakage.

NORTH-EASTERN EXPERIENCES OF YORKSHIRE IRON.

Twelve boilers withdrawn from service	Average age, $18\frac{9}{12}$ years. Average miles, 495,285.
Twelve boilers still at work	Average age, $18\frac{7}{12}$ years; highest, $25\frac{11}{12}$. Average miles, 515,255; highest, 622,521.

The above are all of Low Moor iron.

Sixteen crank axles withdrawn from service	Average age, $14\frac{9}{12}$ years; highest, $22\frac{4}{12}$. Average miles, 378,098; highest, 471,929.
Eleven crank axles still at work	Average age, $13\frac{6}{12}$ years; highest, $14\frac{4}{12}$. Average miles, 283,081; highest, 408,759.

All these are of Yorkshire iron made by Monkbridge & Taylors.

Nine straight engine axles withdrawn from service	Average age, $19\frac{6}{12}$ years; highest, $27\frac{6}{12}$. Average miles, 484,460; highest, 684,328.
Nine straight engine axles still working	Average age, $23\frac{3}{12}$ years; highest, $27\frac{6}{12}$. Average miles, 501,981; highest, 569,766.

All these are of Yorkshire iron made by Monkbridge & Taylors.

On the London, Brighton, and South Coast Railway there are over 350 boilers constructed for a working pressure of 150 lbs. per square inch, some of which have been working since 1871.

)ut of the whole of these not a single plate has been removed, he boiler shells being, in fact, in practically the same condition ıow as when first constructed. The iron for the whole of these)oilers was made at the Monk Bridge Works. There are 12,000)est Yorkshire iron axles of different makes running on this rail-vay, and there has never yet been a failure. I state this on the ıuthority of Mr. Stroudley, the locomotive engineer.

I look at this question from several points of view, and wonder at times why the world has forsaken the old for the new; especially when I find such records as these.

The references to Low Moor recall to my memory an experience of my father, who did business as a locomotive engine builder more than fifty years ago.

In one of his early years he required a plate for a firebox, which weighed a little over 5 cwts. He was told by the manager at Low Moor that it was so big a plate that he would not guarantee to make it, but he would do his best. The plate was made. Now, Mr. Wilson tells me that Messrs. Charles Cammell & Co. have rolled a plate weighing 65 tons. The Low Moor Company can now roll plates 11 feet wide.

This personal experience suggested to me that it might not be uninteresting to you to-day, and it might also be valuable as some record hereafter, to make a rapid comparison between the work of the present and that of the period I have referred to, by giving a few examples of the big things which are now accomplished by the manufacturers of iron and steel, and of the tools with which they do their work.

The development of the manufacture of steel, and the need of more powerful tools to manipulate steel ingots, called for the skill and services of the engineer; and amongst the most remarkable efforts of this age must be reckoned the inventions and appliances of the mechanical engineer.

The splendid discoveries of Sir Henry Bessemer, the inventions and processes of Siemens, owe their success to the wonderful tools and appliances which have been designed and constructed as quickly as ever the need for their services has arisen.

In his presidential address in 1873 Sir Lowthian Bell said, "it cannot be otherwise than gratifying to witness the immense advance which has been effected in the power and excellence of

the machinery in our forges and mills;" but what an advance there has been in the fifteen years which have past since this observation was made.

In my examination of this subject of the improvement of the appliances of machinery to the manufacture of iron and steel, I have found myself embarrassed by so many examples that I am obliged, by space and time, to restrict myself to a few prominent ones. I do not venture to say I am giving you absolutely the biggest things of their kind, but they will serve to review our progress, which is really stupendous, and justifies us in asserting that there is no visible limit in the capacity of the steel trade to provide for the use of the engineer any material of any size or weight which naval service or engineering construction may need, and be willing to pay for.

Blast Furnaces.

Blast furnaces have been exhaustively treated by the addresses to this Institute, in many papers and descriptions.

In the presence of our past-President, Sir Lowthian Bell, the acknowledged first living authority on the blast furnace, I will only venture to refer to them as mechanical developments, by calling attention to the furnace of which I give a sectional drawing (No. 1).

This furnace, at Messrs. Carnegie Brothers' Edgar-Thomson Steel Works, in the United States, produces 2000 tons of pig iron weekly.

At the Edgar-Thomson Steel Works there is a novel apparatus which appears worthy of mention. This is a mixer, a vessel into which all the iron from the blast furnaces is poured from ladles into which the metal has been tapped.

The metal is drawn out as required for the Bessemer converters. The result is stated to be a material reduction in the percentage of defective rails.

Blowing Engines.

Satisfactory working having resulted from the application of the compound principle to blowing engines, the Dowlais Iron Company are now having constructed for their new furnace at

Cardiff engines of this class, to blow either 7 lbs. or 10 lbs. blast, as may be required. A pair of them is shown by figures 2 and 3. The engines will be vertical and direct acting, with the steam cylinders placed above the blowing cylinders.

The boiler pressure will be 100 lbs. per square inch. The blowing cylinders will be 88 inches diameter, and 5 feet stroke; the steam cylinders 36 inches, and 64 inches diameter. The low pressure cylinder will be jacketed; the condenser will have brass tubes 1 inch diameter outside, with 3000 square feet of condensing surface.

Figures 4 to 6 show the arrangement of the engines in the house, with their pipe connections and platforms. The engines are being constructed by Messrs. Kitson & Company of Leeds.

Cogging mills, reversing rolling mills, shearing machines, hydraulic charging machines, leviathan steam hammers, testing machines, live rollers, hydraulic forge presses are new mechanical appliances which have been devised to assist in carrying on the manufacture of iron and steel.

I am unable from lack of space to name the appliances surrounding the Bessemer converter or the cranes and contrivances which serve it.

Hydraulic pressure has permitted the use of numerous labour-saving appliances. Amongst the most ingenious and useful of these tools, I would name the hydraulic charging apparatus, of which I present drawings (figs. 7 and 8) kindly supplied to me by Mr. Evans, the general manager of the Barrow Hæmatite Steel Company.

This hydraulic charging apparatus consists of a fixed centre with a long arm which is carried on wheels at one end, and is attached to the fixed centre at the other. It is revolved by two hydraulic cylinders and rams attached to the arm, with chains working round the fixed centre. The peel is raised or lowered by a hydraulic ram at the end of the arm. By means of this apparatus, the same men at the same hammer turn out four times the weight of hammered ingots that they formerly produced.

Live Rollers.

Live rollers have been designed which convey the ingots to the cogging and finishing mills, and afford a great economy and facility in the transport of the ingots. The best example of live rollers I know is that of the Barrow Steel Company. The

ingots are transported by live rollers to the cogging mill, and from this point to the receiving bench (fig. 9).

The rails travel in one direction only, and are conveyed entirely by mechanical means a distance of 553 feet.

The whole design is an admirable example of modern practice in the application of mechanism to the transport of material in the course of manufacture, and reflects the greatest credit on those who suggested and those who engineered the work. This mill could roll 5000 tons of rails per week if continuously fed with ingots.

Live rollers are now also used in plate mills, not only to feed the mill but to traverse the plates from roughing to finishing rolls, and so much is the output thus increased that at the Consett Iron Works, Mr. Jenkins tells me, they have rolled in one turn 105 tons of marketable plates, which is equal to an output of 1000 tons of plates per week. This make is achieved steadily week by week.

Twenty-five years ago it was considered very good work to turn out 250 tons in one week.

This plate mill is of the lever clutch reversing type, having grain and chilled rolls each 8 feet long by 28 inches diameter.

The top chill is balanced, as well as the grain, by weights. The plate, after being reduced to a thickness suitable for finishing, is traversed by steam power to the chill rolls, where on the front side is provided a fixed platform with live rollers as above.

The engine has one steam cylinder, 45 inches diameter and 5 feet stroke, and a flywheel weighing 50 tons.

Shears.

The 5-cwt. plate I named was sheared in the old crocodile shears, cutting 12 inches long by $\frac{3}{4}$ inch thick.

The latest large shearing machines, of which I give a drawing (fig. 10), as an example of one made by Messrs. Joshua Buckton & Co., Leeds, which cuts a steel plate 2 inches thick cold, with a blade 10 ft. 6 ins. long. It will cut a plate 7 feet wide across the middle at one stroke.

A machine of similar design is being constructed by Messrs. Bolckow, Vaughan, & Co. to cut 2 inches thick with 9 feet between the standards and 4 ft. 6 in. reach of gaps. The large shearing machine (fig. 11) cuts steel slabs 3 feet wide by 11 inches thick.

A similar machine for cutting blooms 30 inches wide by 11 inches thick cuts regularly 2000 tons of measured slabs per week at the Consett Works.

Testing Machines.

Diagram No. 12 shows a testing machine made by Messrs. Buckton of Leeds for H.M. Dockyard at Malta. It will break a cable made of $3\frac{1}{2}$ inches diameter iron, and test up to its proof load a cable made of $4\frac{1}{2}$ inches diameter iron. It will admit and test anchors of the largest Admiralty pattern. Also, it will crush, twist, bend, or shear specimens of steel up to 3 inches diameter. It admits 80 feet long between the shackles, and the hydraulic straining ram has 7 feet stroke.

Steam Hammers.

A reference to the steam-hammer has a special interest at this moment, as it is a tool which appears to have reached its fullest development.

In fig. 13 I give you an elevation of the 100-ton steam-hammer at the works of Messrs. Schneider & Co.

This hammer is 19·60 metres high, its cylinder is 1·900 metres diameter, and it has a stroke of 5 metres, and an anvil-block weighing 750 tons.

Alongside of this I give a drawing (fig. 14) of the first steam hammer erected at Le Creusot in 1840.

The 50-ton steam hammer of Krupp, Essen, Germany, is the earliest of the big steam hammers of Europe; it was built from the designs of the late Mr. Alfred Krupp in 1861. It is shown in the drawing No. 15, which was kindly supplied to me by Mr. Longsden. The falling weight or tup weighs 50 tons, and the anvil block weighs 1100 tons, a proportion of block to tup which is wisely largely in excess of that of the French hammers; —the anvil block of the Creusot hammer being $7\frac{1}{2}$ to 1, of the 100-ton hammer of Marrel Fréres 5 to 1, and of Krupp's block 22 to 1.

There are four steam cranes for the service of this hammer, two of 30 tons each, and two of 60 tons each.

I have extracted from a most valuable *mémoire* on steam hammers by Messrs. A. & Ch. Casalonga a list of the big steam hammers of Europe.

The heaviest steam hammers in operation at the present time are :—

In England—

1	double acting	30-ton	hammer at	Elswick.
1	„	35	„ „	Woolwich Arsenal.

In Germany—

1	„	50	„ „	Krupp's.

In Russia—

2	„	50 „

In France—

4	„	20 „
3	„	25 „
1	„	35 „
2	„	40 „
1	„	50 „
1	„	80 „
2	„	100 „

The reason and the effect of this overwhelming array of big hammers in France, are that French manufacturers have been encouraged by continuous contracts to undertake the great responsibility of the outlay required, and they have furnished a continuous supply of heavy artillery for the forts and the navy of France.

Fortunately, the steel forging capacity of England is not represented by a comparison with steam-hammer power.

The forging presses of Whitworth, Vickers, Brown, and Cammell have a capacity in excess of this array of French hammers.

The days of the giant hammer are numbered, and the Titan you see here, whose blow disturbs and injures a whole district, will be supplanted by the silent, slow-working, but irresistible press.

In this new application of mechanical science English steel manufacturers are distinctly well ahead of their foreign competitors, who are only just beginning to derive from England the tools which have long been used and perfected by the makers I have named.

I was permitted the other day, by the kindness of Mr. J. D. Ellis, to view the 4000-ton press of Sir John Brown & Co., which was made by Messrs. Tannett, Walker, & Co., of Leeds.

The press was working upon an ingot, the original size of which was 52 inches diameter at the bottom, 46 inches diameter at the top, and about 34 tons weight. This was reduced in four heats to 29 inches diameter for a gun tube 28 feet long.

The forging press of Messrs. Cammell & Co. (fig. 16) was made by Messrs. Davy Brothers of Sheffield. This is a 5000-ton press. Mr. Charles Davy has been good enough to furnish me with much valuable information on the subject of press forging.

This subject of hydraulic press forging is one which I hope will be brought before this institution by one of our members. We have several well qualified to inform us upon it.

A warm acknowledgment should be made of the inventions of Haswell of Vienna, who was the pioneer in this field, his presses having done much work on the Continent in the forging and shaping of iron during a long period of years.

When the history of the forging of metals by hydraulic pressure is written, it will not be complete without a record of the invention of our own Sir Henry Bessemer.

In 1856 Sir Henry Bessemer obtained a patent for the first application of hydraulic pressure in the manufacture of steel in its fluid and solid state, and in August 1856 a press, drawing No. 16, was shown at work at his experimental steel works at St. Pancras; in August 1869 Sir Henry Bessemer was granted a patent for the further development of his system of casting under pressure, and in January 1863 he patented a hydraulic forging press, which is shown in drawing No. 17.

I have a long and interesting letter from Sir Henry Bessemer on the subject, which I hope to have some other opportunity of communicating.

His inventions cover a large field, and are the fruit of more than sixty years of mental activity.

May he long live to enlighten and to counsel us with his practical experience, aided by his scientific knowledge, and to encourage us by his presence!

In endeavouring to make a comparison between the force of a steam hammer and a forging press, we must consider the differences in the application of the pressure.

The blow of a hammer is instantaneous, the effort is abrupt, and it is expended in a very short space of time, consequently the metal is forced into shape suddenly. The force of the blow is absorbed to a great extent on the surface of the forging, and if the hammer is under its work, the surface absorption is so great that the forging has a tendency to pipe, and to become hollow and unsound in the centre.

On the table are two specimens of steel, supplied by Mr. J. D. Ellis, one hammered, the other pressed, which clearly demonstrate the action of the hammer and the press.

A hammer of 100,000 kilogrammes falling weight, has a nominal travel of 5·00 m., which is reduced to 3·50 m. if operating upon an ingot 1·15 m. thick.

The work done in lifting the hammer is $100{,}000 \times 3{\cdot}50 =$ 350,000 kilogrammes.

The work or energy given out in arresting the descent is necessarily equal to the work done in lifting; assuming that the velocity of descent has not been restricted by back pressure in the steam cylinder. The velocity of descent is, however, considerably restricted, part of the energy being expended in forcing the exhaust out of the cylinder. There is a loss due to friction as well.

The amount of penetration effected, as represented by the distance travelled in arresting the descent of the hammer, is dependent on the superficial area of the hammer face, and on the hardness or softness of the ingot. Assuming the disposable work of the falling hammer to be 350,000 kilogrammètres, and the penetration to be 0·10 mètres, it follows that the mean resistance will be 3,500,000 kilos., but the falling weight will be capable of exerting a much larger pressure on its first contact with the forging. The whole operation of bringing the falling part to rest occupies so little time that it is impossible that the pressure of the blow can be felt equally and uniformly throughout the metal.

A press dynamically equivalent to the above hammer would be capable of exerting a constant pressure of 3,500,000 kilos., and the diagram of energy would be a simple rectangle. The time required to effect the compression would be several seconds.

As the hammer cannot develop the full amount of energy stored in raising the tup, it is certain that a press of less than 3500 tons power would be equivalent to a 100-tons hammer.

Electrical Welding.

Electrical welding is a process which now has a practical value, and the perfecting of which will afford further opportunities to the engineer, and lead to new applications of iron and steel.

The Thomson electric welding machines are now, I am assured, in use in the United States for welding iron, steel, and other

netals. The weld is as strong as the same section in another part of the bar, as the heat is first developed in the interior of the part to be welded, and joins thence outwards as pressure is applied to it.

It is claimed that, by the use of specially adapted holders, locomotive frames, angle iron, pipes, T connections, carriage and waggon ironwork, &c., and possibly boiler plates, can be thus electrically welded. Rivets are to be heated by electricity when in the holes, having first been fixed when cold.

This opens out a new prospect of expansion. Locomotive boilers and marine boilers, electrically welded, will enable our engineers to work with pressures of which we can only dream at present; and new economies in compounding will still further develop the transport and exchange of commodities, and create new fields for the use of iron and steel.

Water Gas.

Water-gas has valuable qualities ascribed to it, from which economy and purity of product are obtained. The subject is an extensive one, and large interests are involved. The Council has invited members of this Institute who are concerned in the invention to bring this process before you by papers, by which means it may be explained and discussed.

Alloys.

Much attention has during the last few years been paid to substituting the carbon contained in steel by a metallic substance, thus forming iron alloys, which are bound to play a more and more important part in industry on account of their special nature and qualities.

Chemically pure metallic iron is practically unknown. Iron containing a very small quantity of carbon is as soft as lead, and when exposed to a moist atmosphere it oxidizes very quickly. Wrought or ingot iron containing say 0·08 of carbon must already be considered as a compound in the stage towards steel. Ingot iron alloyed with so small a proportion of aluminium as 0·1 per cent. melts at a comparatively low temperature, is very liquid in the molten state, and can be cast into solid and homogeneous objects possessing the strength of wrought iron.

The Aluminium Company, which has succeeded in producing aluminium of practically absolute purity, has kindly sent in some samples of their productions, which are on the table before you, embracing examples of ferro-aluminium, aluminium-wire, aluminium-rods, and other objects.

These alloys are finding a large application on account of the facility with which they are cast, and on account of their strength and ductility; but they are subject to the corrosive influence of moist atmosphere, salt water, &c., in the same, or somewhat larger, degree as iron or steel, whilst alloys of copper are much improved in strength and ductility by the introduction of a certain proportion of iron.

These alloys, provided the iron is chemically combined, are not acted upon by moisture, sea water, &c.

I exhibit samples of Delta metal, which is an alloy of copper, zinc, and iron; the latter is introduced after being previously alloyed with zinc. A sample on the table of this zinc iron alloy, containing 22 per cent. of iron and 78 per cent. of zinc has the appearance of a mineral, and by no means that of the metals of which it is composed. That the iron here is chemically alloyed is proved by the same not attracting the magnet; neither does it rust when exposed to a moist atmosphere, nor give sparks under friction.

Delta metal, although containing only about 2 per cent. of iron, shows when cast in sand, equal tensile strength to wrought iron, viz., 23 to 24 tons per square inch, and when forged or stamped, at a red heat its strength is increased to about 38 tons per square inch, with 20 per cent. of elongation.

Launches and torpedo boats made of Delta metal sheets have been in service some years, exposed to the action of river and sea water without showing signs of deterioration.

I am glad to say that the subject of the alloys of nickel and iron will be treated in a paper by Mr. James Riley, a member of Council. This alloy promises to be of great commercial value.

I have here test-pieces of two bars which were cut out of a 10-ton armour plate made in France. The pieces were forged down into shape. They contain 5 per cent. of nickel, and give a tensile strain of 90 tons, with an elongation of 8 per cent. It is claimed that with 5 per cent. of nickel there is almost entire

freedom from corrosion. Nickel steel has extreme fluidity, and is very sound.

It is evident that a full consideration of this subject of steel alloys will be of great value and interest to the members of this Institute.

Having seen how appliances and methods are increasing our manufacturing capabilities, it is well that we should glance at our prospects and opportunities of using them.

In construction works the successful completion of the Forth Bridge, which is now assured to be effected during this year, 1889, will afford an example of the possibilities of bridging rivers and valleys, hitherto impediments to direct communication.

This triumph of engineering skill, and of practical work, stands as a remarkable testimony to the merits of steel, and again shows how opportunely a need is met by a new production.

English architects are no longer behind their Continental brethren in the use of iron and steel for architectural purposes, and the ever-increasing employment of iron and steel from this development is assured.

Ships.

In considering our future the condition and prospects of the shipbuilding trade are of vast concern, and it is a great encouragement to know that there is an active and a healthy demand for ships, which we can reasonably estimate will for some time be steady and advancing in its quantity.

I find from Lloyd's Register of Shipping that there are at present under construction in the United Kingdom 528 vessels, having a gross tonnage of 920,989 tons, being an increase on the same period last year of 148 vessels, and 326,563 tons.

Roundly speaking, half a ton of iron or steel is required per ton of gross tonnage, and taking the annual production now required and contracted for as 1,000,000 tons, we have reasonable grounds for calculating upon a demand for some years to come of 500,000 tons of manufactured iron and steel from this source alone.

It is encouraging to notice that 398 vessels, having a gross tonnage of 700,000 tons, out of 1,000,000 tons, are building for the United Kingdom.

Railroad Requirements.

Heavy and powerful engines have been constructed to draw the express trains at higher speed, which serve the great cities of the Continent.

The limits of these services are restricted, as yet, by the capacity of the railroads.

The rails in service on the main lines of this country have been laid down, in recent years, of heavier and stronger sections, and although they have not yet attained their maximum, they are distinctly better than those of most of the principal Continental and Colonial lines.

My friend, Mr. Sandberg, the inventor of the Goliath rail, and an authority on the subject, has presented an interesting paper on the use of heavier rails to the Institution of Civil Engineers. He related the history of the accident to the Czar's train on the Kursk-Charkov-Azov Railway.

The train, weighing nearly 600 tons, including the Czar's sleeping carriage, which weighs about 50 tons, was run at 43 miles an hour on a 66-lbs. rail and an imperfect road. The train ran off the line and was wrecked, and many persons were killed.

This condition of road and rail exists on many Continental main lines of railway on which heavy express trains are running, and it is imperative that such lines should be relaid to meet the new conditions of railway service.

Some Colonial lines have recognised this new want. The Victorian Government railways are now taking from the Barrow Steel Company the Goliath rail—a flat-bottomed rail 100 lbs. per yard, a section of which lies on the table.

Technical Education.

I will not treat you to anything more than a passing remark on the subject of technical education. It is very clear that elementary training in physical and mechanical science, and in drawing, is essential to the managers of iron and steel works. A glance at the list of subjects which engages our attention this week is proof enough.

An intelligent German, quoted by Sir Henry Roscoe, made the observation, "Whilst you in England have been busy for the last

half-century in perfecting your machines, we in Germany have been busy in perfecting our men."

There is sound truth and serious warning to us in this observation, though it is open to the retort that English machines and English inventions have been perfected by Englishmen.

Still, manufacturers and workmen like myself, who can but touch the fringe of scientific knowledge which rules and develops our processes, are conscious that we must do our utmost to secure for our workers scientific training, which shall afford to the rising generation a wider knowledge and a fuller light.

Conclusion.

It is well for us that we meet to-day under better trade conditions and with brighter prospects than we have enjoyed for some time past. The revival of trade, which is general, has *not* happily reached the iron and steel trade through any *special* source.

It is no American boom, but a world-wide demand which has infused life and general activity into our furnaces and our rolling mills.

This is not an Institute for the consideration of commercial questions, but I will venture to utter one word of counsel with the experience of the past years so full upon us.

The inflation of the years about 1873 led to an unreasonably rapid development of the means of production throughout the world, which was not followed by a corresponding increase of the needed demand. The facility which limited liability laws give for the acquisition of capital for new works, enables new plant to be laid down at a rate and on a scale which was impossible to our private concerns, which grew out of profits made in the business.

So, although developments were not denied, they were, it seems to me, of more natural and more healthy growth.

Years ago an old friend of the town of Leeds, Sir Edward Baines, in a speech on commercial matters, quoted a Latin motto, that sank into my mind as one which ought to be remembered by commercial men. It was *Festina lente* (Make haste slowly).

It is true that all iron and steel works in this country are actively employed, many with forward contracts, but the make is immense.

In the United Kingdom we produced in the year 1888 169,935,219 tons of coal, exceeding by 6,198,219 tons the largest output of any previous year in the history of the trade.

We produced 7,898,634 tons of pig iron, 2,012,794 tons of Bessemer steel ingots, and 1,292,742 tons of open-hearth steel ingots. And we must remember that we began this year with a stock of 2,516,212 tons of pig iron, which is decreasing but slowly.

We have alert and instructed competitors in every neutral market, while fiscal restrictions interfere with our trade in most Continental countries. Any serious advances in the price of materials would endanger the trade we are now securing.

Let us develop our appliances, and improve our processes with care, prudence, and wisdom, then will our progress be sound and secure.

Festina lente.

Sir J. W. PEASE, Bart., M.P., said that a very pleasant duty had been placed in his hands—one that he certainly should not have allocated to himself, for he felt that he was surrounded by those who had devoted long lives and great talent to the development of the iron and steel trades, while his own humble department had been rather that of the £. s. d. connected with them. It was with the greatest pleasure that he had entered the hall and seen one of his oldest friends in the trade, Mr. Daniel Adamson, in the chair. Although many of them had known Mr. Adamson for long years, he thought that he had had the satisfaction of working with him over a much longer period than any one else. Then he had also had the pleasure of seeing a personal friend, and the son of a very old personal friend, taking the chair in succession to Mr. Adamson, and he had had the satisfaction of listening to his address, which was so full of interesting historical record and of sound advice. It was his good fortune to know how very sound and practical a man the new President was, and he heartily moved—

"That the best thanks of the meeting be, and are hereby, tendered to the President for his admirable and interesting address."

He had listened to the latter part of that address respecting the great inventions of the present time with almost more interest than he did to the first part, interesting as that was, because it led him to think of many of those men whose portraits were on the

walls of the Institution whose guests they then were, and of the many difficulties with which they had had to contend as compared with the difficulties experienced by civil engineers in the present day. It would not be easy to justly distribute the praise or the blame where it was deserved, but all would admit that the work and the call of the engineer had made the enterprise of the country what it was, and the enormous changes referred to by the President were amongst the more surprising things that had taken place in the lifetime of any of them. He was the possessor of a letter which he greatly valued, written by old George Stephenson to his grandfather, Mr. Edward Pease, in which he earnestly begged of him to consider how far cast iron rails should be used for the Stockton and Darlington Railway, and he went on to say:—"I think we could secure something like three or four feet, or perhaps up to six feet, good casting, while I do not see where we could procure a wrought iron rail of anything like that length with accuracy, either in its substance or in its forging." That showed that almost within their own lifetime those enormous changes had taken place to which reference had been made by the President.

Sir LOWTHIAN BELL, Bart., F.R.S., said that a long friendship, that had never known a moment's interruption, and a very intimate knowledge of the judgment of Sir James Kitson for some years past had induced him to recommend his friend to undertake the duties of President of the Institute which had been assigned to him by the Council. He was quite sure that the manner in which he had discharged his work that morning would be accepted by the members as an ample justification for the recommendation which he (Sir Lowthian Bell) had made. His friend had pleasantly observed that, so far as his own observation was concerned, steel appeared to have had a great deal of its own way at the meetings of the Iron and Steel Institute, and he thought it was only fair that Yorkshire iron should have its turn. Yorkshire iron had now had its turn, and no one who had listened to the manner in which the President had advocated the claims of that material could deny that he had discharged his duty in a most impartial manner. If Sir Henry Bessemer himself had drawn up a comparative statement with reference to the claims of steel and York-

shire iron, he could not have discharged his duty in a more impartial way than had been done from the chair. His friend went on to say that it had been a threatened industry. It was always dangerous to prophesy. Many of them remembered that on the introduction of railways it was said that horses would be entirely disestablished, but so far from that being the case, they all knew that railways soon employed more horses in mere terminal work than ever had been engaged in carrying on the former intercourse of the country. But the cases were not quite parallel. Although the old West Yorkshire puddling furnaces were now fully employed, there was a sad tale to tell of many puddling furnaces in other parts of the world. He had been delighted, as he was sure all the members had been, at the very excellent display of articles brought there by the President—deeply interesting to all manufacturers of iron. He had listened with great pleasure to the description of the colossal furnace referred to from the chair. Dealing with the question in a comparative sense, his friend had brought to his recollection a furnace visited by him (Sir Lowthian Bell) half-a-dozen years ago in Savoy, a furnace about twelve feet high, and making as much iron in a week as the furnace referred to by their President was now turning out in an hour. After having spent some time in examining that primitive structure he went into the office, and the gentleman was kind enough to show him his charging sheet. He afterwards said to him, "Accustomed as you are to the vast establishments of England, what possessed you to visit an out-of-the-way place like this in order to see a little insignificant furnace like the one you have just examined?" His reply was, "I never knew what I might or might not meet with on such visits as this." The gentleman then asked if he had seen anything novel, and he replied, "Yes; this is the first time I have visited a smelting establishment in which the charging book was so nearly the size of the blast furnace of the work of which it contained a record." He begged heartily to second the vote of thanks which had been proposed by Sir Joseph Pease.

The motion was unanimously adopted.

The PRESIDENT said he desired to thank the members for their

kind reception. The resolution was doubly gratifying to him as having been proposed by the head of the house of Pease (a family which had done more for the railway interest of the country than any family that he could name), and seconded by a very old and kind friend of his father, and one who occupied so distinguished a position in the Institute.

He would now call upon the Secretary to read a letter which had been received from the United States.

The SECRETARY then read the following passages from a letter written by Dr. Raymond, Secretary of the American Institute of Mining Engineers:—

"I have the pleasure of informing you that a resolution was unanimously adopted at a meeting of my Council held here (New York) to-day (April 10), instructing me to extend to the Iron and Steel Institute a cordial invitation to hold a meeting in the United States in the autumn of 1890, and to unite in one or more joint-sessions with the American Institute of Mining Engineers at such time and place as may hereafter be agreed upon.

"Mr. Andrew Carnegie has been appointed chairman of our Committee of Arrangements; but the organisation which will ultimately be made, in case of the formal acceptance of the invitation, which your despatch has led us to expect, will represent not only our own Society, but the Societies of Mechanical and Civil Engineers, and other bodies, as well as the iron and steel business generally. There is no intention or desire on the part of the Institute of Mining Engineers to monopolise in any way the honour and pleasure of this visit."

The PRESIDENT said that the members would be glad to know that they had present with them a gentleman from the United States who had been for many years one of the leaders of the Free Trade party in that country, to which British iron manufacturers and merchants always looked as a market with very longing eyes. Mr. Hewitt had been a prominent member of the House of Representatives, and also a distinguished Mayor of his native city, New York. He had still another relationship which endeared him to the Institute: he was the son-in-law of Mr. Peter Cooper of New

York, who was a Bessemer medallist and a distinguished honorary member of the Institute. Mr. Hewitt had been good enough to promise the Institute a portrait in oils of his father-in-law, and he would perhaps be kind enough to say a word by way of endorsing the invitation which had been read.

The Hon. A. S. HEWITT said that he trusted that his mission would be as acceptable to the members as it was agreeable to himself. He had been asked by the American Institute of Mining Engineers to endorse in person the invitation which had been read by the Secretary, and which, as he had understood since his arrival, had practically been accepted by the Iron and Steel Institute. It would be a source of immense gratification, not only to those engaged in the same business as themselves, but to the members of all the scientific bodies in the United States, and particularly to the great masses of the people who were engaged in industrial pursuits in his country, that so powerful, and, he might add, so beneficent, an Institute saw fit to be their guest for a brief period. He had been told that the visit had been proposed for the year 1888; he so understood from the report to which he had listened. When that purpose was brought to the notice of the members of the Institute resident in America, and to the iron trade generally, it was felt that the time selected was rather inopportune, because the Presidential election took place in that year, and it was believed that the visit of the members in that year might be considered by certain persons, particularly by their omniscient and omnipresent newspapers, as an attempt on the part of the Iron and Steel Institute—which, he was glad to say, was free from all political complications—to put forward the cause of Free Trade, to which the President had alluded. He, for one, was not afraid of anything that their influence might do in that direction. On the contrary, he fully believed that they had more to fear in England from universal Free Trade than they had in America. They might be sure, however, that they would receive a warm welcome.

He remembered many years ago being at a dinner of the Institute at Birmingham, one at which the late Lord Dudley presided and he had then alluded to the fact that in his (Mr. Hewitt's log-cabin in the mountains of New Jersey there was such an a re-

ciation of what the British iron trade had done for the world, and of what one great inventor in particular had accomplished, that the bust of Sir Henry Bessemer stood beside the door, outside which hung a latch-string for all comers to come in and admire. The log-cabin was still there, the bust of Sir Henry Bessemer was still there, the latch-string was still there, and the same primitive invention for getting admission to the hearts and homes of primitive races would be found on every door in America when they chose to go there.

The President had been good enough to allude to the fact that the Institute had conferred the Bessemer medal upon Mr. Peter Cooper. The Institute had endeared itself to the hearts of the American people when that act of generous recognition was performed. For ninety-three years that gentleman had lived a life of beneficence which had given him a place in the memory and in the hearts of every American; and among the many honours which he had received, and his many titles to a distinguished reputation, none was ever so grateful to him and to the American people as the gift of the Bessemer gold medal, because it recognised, not so much that he had any title to that great distinction, as the fact that great discoveries and noble deeds belonged to no people and no race, but were the universal property of all mankind.

The address of the President had satisfied him, after an absence of some years from the British soil, that they might perhaps have to come to England to school; but they meant to show the members some things that would interest them, and particularly the promptitude with which they applied the inventions that, through the agency of the Institute, were made the property of the whole world. They could also show them that the great basis upon which civilisation rested was not likely to be exhausted by the efforts of Englishmen or Americans within the period during which the circling globe should continue its annual revolutions. They felt that their English brethren were displaying great confidence in entrusting themselves to American shores. They had sent much of their property across the Atlantic, and the Americans had done their best to keep it. They would also be very glad to supplement it by possessing themselves permanently of the personal presence of the members of the Institute. They knew that that was too large a hope to

cherish, but they were sure that after an acquaintance with them in their homes their British friends would return with a feeling that the old country had produced a race of not ungrateful children. There was only one thing that disturbed him. The Council, in their report, had alluded to the intention of the Institute to abolish the free lunch. Now, if there was anything that the American constitution had secured to the people, it was the free lunch. It formed part and parcel of every saloon and inn in the United States. Englishmen would be surprised at the generosity with which free lunches were distributed to those who did not expect to get free drinks. He hoped that the Institute would postpone final action upon that most important question until they had visited America, because their American friends did not desire to be handicapped in that particular. Perhaps when the members had become acquainted with the American free lunches, their terrapins, and their canvas-back ducks, to say nothing of the oysters, of which they appeared to have a very imperfect knowledge in England, they would be better reconciled to the perpetuation of what he had found, during a whole lifetime, to be the characteristic of the British nation—unbounded hospitality to the stranger who came among them.

Mr. T. BARLOW-MASSICKS said he had been requested to propose—

"That this meeting of the Iron and Steel Institute expresses its cordial thanks to the Hon. Abraham S. Hewitt for his address, and cordially endorses the resolution of the Council to hold the autumn meeting of 1890 in the United States."

It would need no words of his to convey to Mr. Hewitt how highly they appreciated the cordial invitation that had been extended to them, and the kind way in which he had endorsed it. On the previous evening he had had the pleasure of hearing Mr. Hewitt descant upon much that they were to see in the United States, and on its great mineral wealth, but he went away from the meeting (it might seem a hard thing to say it) a most unhappy man. He was himself a large mine-owner and a maker of pig-iron, and the mining industries of America had filled him with nothing but envy and dismay. This state of feeling was not

improved when he heard their President that morning talk about a furnace making 2000 tons of pig iron per week, seeing that he had as large a furnace not making 1000 tons. However, they would endeavour to find out the secrets of their American friends as well as they could. What the Americans took from this country the British members of the Institute would endeavour to bring back with interest. If he had not been reading Mr. Brydges' famous book on the "Uncle Sam at home," he should have felt disposed to think that much of the richness of the land was a mere fable; but he was bound to believe it all. He had pleasure in moving the resolution, and he had no doubt that the members would enjoy all that was promised them amongst their brethren in the United States.

Mr. JOHN ROGERSON, in seconding the motion, said that thirty years ago he had a letter of introduction to Mr. Hewitt and Mr. Peter Cooper from Robert Stephenson. He received a kindly welcome, and was informed that there would be a knife and fork at his disposal at Mr. Peter Cooper's table, of which he frequently availed himself. The members might be quite sure that when they visited the United States they would receive a hearty welcome. He might take the opportunity of mentioning that Mr. Hewitt was present when the Atlantic cable was first proposed, and Mr. Peter Cooper was one of those, in connection with Mr. Hewitt, Mr. Cyrus Field, and one or two others, who made overtures to Sir George Elliot to produce that cable. He was not quite sure that Mr. Hewitt himself was not the first to come to Sir George Elliot, who had told him that he negotiated with Mr. Hewitt and Mr. Cyrus Field for the manufacture of the cable. Thirty years ago Mr. Hewitt's brother stayed some time at the Consett Ironworks, and he (Mr. Rogerson) had the pleasure of taking him over the large ironworks in the north of England. With those few remarks, and bearing in mind that Mr. Hewitt was the son-in-law of Mr. Peter Cooper, who was almost the inventor of the locomotive engine at Baltimore, he had much pleasure in seconding the motion.

The motion was passed by acclamation.

Bessemer Gold Medal for 1889.

The President said he had to inform the members that the Council had decided to present the Bessemer medal for the present year to Mr. J. D. Ellis, of Sheffield. They had heard much that day, and on previous occasions, of scientific inventions; but inventors and scientific men generally would be the first to acknowledge that without the energy, the experience, and the resolution of practical men their inventions would be of no avail. Mr. Ellis was a man who had been very closely engaged in the development of the iron and steel trades, and the Bessemer invention, as Sir Henry Bessemer would himself tell them, owed much to the energy and the enterprise of Messrs. Sir John Brown & Co., who, in 1861, were the first house in Sheffield to take a license from Sir Henry Bessemer to work his invention. Prior to that, Sir Henry Bessemer himself, with the assistance of Mr. Allen, had been carrying on his experimental works in Sheffield; but Sir John Brown, and particularly his partner, Mr. Ellis, took up the invention, and their developments contributed materially to its successful adoption throughout the country. Mr. Ellis was one of the first to introduce the Bessemer steel rail, and he had learned that when they first introduced it they had some difficulty in taking orders, as the price which they required was £22, 10s. per ton. But notwithstanding that price, and perhaps because of that price—for it showed clearly the merit of the steel rail—they continued, and they made and delivered large quantities of steel rails to various railway companies in England and throughout Europe at from £18, 10s. to £19 per ton. He had no doubt that some of his steel-making friends would be pleased to hear those prices mentioned, and to hear that Mr. Ellis had told him that their agent in St. Petersburg at one period pressed them as a particular favour to enter, for the Russian Railway Society, an order for a few thousand tons more at £19 per ton. In 1861 Sir John Brown & Co., under Mr. Ellis's direction, took up the manufacture of armour-plates, and they were the first house in Sheffield to make armour-plates. Mr. Ellis was the successful patentee and manufacturer of a steel-faced armour-plate. Mr. Ellis had told him that he had been engaged in steel-

naking about thirty-five years. He was not sure whether he was correct as to the period when the firm of John Brown & Co. commenced, because Mr. Jeans, in his antiquarian researches, had ascertained that, in 1635—

"The Lords of the Admiralty, having regard to the fact that it was very important that the manufacture of iron ordnance should be encouraged, proposed to give John Brown & Co. the right to have the sole manufacture of iron pots, kettles, backs of chimneys, salt pans, pitch pans, and such like." It was reported, at the same time, that "the Swedish ordnance had so beaten down the market beyond the seas that the petitioner makes no ordnance for exportation, and only a small quantity to supply the market in England, and unless there be some other employment to keep the petitioner and his servants at work, they will be compelled to seek employment beyond the seas, and the trade of making iron ordnance, first invented in England, will be lost."

It was very interesting to note that, because they were now under very different conditions. In taking up new inventions, and putting down expensive plant, manufacturers had now to rely upon their own judgment of the market, and their own capacity to manufacture. They saw that the firm of Sir John Brown & Co., now directed by Mr. Ellis, were putting down giant presses, and making steel ordnance, not only for England, but for the world. In recognition of that development of the Bessemer process, and the dogged enterprise of a practical man, the Council had commissioned him to present Mr. Ellis with the Bessemer medal. Before Mr. Ellis acknowledged the receipt of the medal, perhaps Sir Henry Bessemer would like to say a word.

Sir HENRY BESSEMER, F.R.S., said he thought the President had gone into this question so exhaustively, and, in addition to that, the firm of Sir John Brown & Co., of Sheffield, and their productions, were so intimately known to them, that if he were to tell them of it as something new it would be like telling them that in Great Britain there was a place called London. He thought they need not be told that; and as they need not be told that, he thought he could add very little indeed that they did not know with reference to that great enterprising establishment known as Sir John

Brown & Co., of Sheffield. It was many years ago since he established a small works at Sheffield, bordering, with only a wall between them, the premises occupied by John Brown & Co. He was forced to do that from the fact that steel-makers by the old plan had no belief whatever in the possibility of making pig iron into steel in twenty minutes; and as he could not enforce the fact upon them, it was necessary that he should compete with them in their own market; and that was the reason he established himself in Sheffield, wishing all the time that the Sheffield manufacturers could see things in the same light that he did; but they did not. For some considerable time his little works were going on, and it was not until they lowered the price of almost every article that they were producing some £10 or £20 below the then prices of Sheffield that Sheffield manufacturers began seriously to think that, after all, there was some little merit in what Bessemer was doing. He must also say that the first and most intelligent of all the steel men of Sheffield were in the works of John Brown & Co., and their practical man, Mr. John Ellis, was actually the first man in Sheffield to come to the conclusion that the new process was worth looking at. Mr. Ellis came into the Bessemer works, and saw what they were doing, and in a very few days from that time the firm had arranged to take a license under his patent. They put up the first working apparatus, beyond the Bessemer Works, that was ever used in this country, and the President had told them to what good tune they had applied it.

One almost felt envy at the idea of rails selling at £18 and £19 per ton, when they could not have cost very much more than they did to-day. However, he would not grumble at the success—so well deserved—of those who were able to distinguish that the new process was one which had at least some merit in it, and he could assure them that when the Council of the Institute voted the annual medal of this year to Mr. Ellis, it was with his (Sir H. Bessemer's) entire and most cordial satisfaction—a feeling that, as a practical man, Mr Ellis had done everything that could have been done to entitle him to that distinction.

Mr. J. D. ELLIS said he felt under such a great obligation to the President and to the members for the kindness he had received

from them that he scarcely knew how to reply to the remarks that had been made by the President and Sir Henry Bessemer. Not only had he to thank them for the beautiful medal, which would be greatly esteemed by him as long as he lived, but he was also grateful to them for having been elected a member of the Council, which he regarded as a very great honour. He did not know that he was ever more surprised than he was at one of their recent meetings, when Mr. Daniel Adamson, in proposing the gentleman who should receive the medal, began by stating what he knew about him, what he had done, and what an excellent man he was. He thought of nearly all his friends, but he could not for the life of him recognise who it was that Mr. Adamson was talking about, and when at length his name was mentioned, he was perfectly astounded. The Council, however, had been kind enough to confirm what Mr. Adamson had suggested. The President and Sir Henry Bessemer had gone rather fully into some matters with regard to the early working of the Bessemer process which he (Mr. Ellis) had intended to lay before them; but there were one or two things which they had not named, perhaps because they had never come to their knowledge. A remark had been made that morning that when things were evidently wanted, they frequently came to the surface. He did not suppose that many present were aware that about the year 1859, when railways were increasing considerably both in length and in speed, they suffered very much from the inferiority of the iron rails, which frequently had to be taken up. Two or three years before that, Mr. Brown and himself had introduced into the town of Sheffield the manufacture of what they called steel-iron. It was used for making springs, instead of the Swedish iron which had been previously employed for that purpose. It occurred to them that they could make a very excellent rail of that steel-iron, and they actually erected ten converting furnaces for the purpose of converting bars or blooms of steel-iron, intending afterwards to roll them into rails. They would have been something like what might be called puddled-steel rails, and he had no doubt that the material would have been very valuable. But it so happened that at that time Mr. Bessemer had started, with the assistance of Mr. Allen, the works of which he had been speaking. He one day went to see the process, and he was so

struck with it that, on seeing a small heat blown, of perhaps a ton or 30 cwt., and seeing also an ingot hammered into a bloom, he went straight to Mr. Brown and said, "These furnaces will be of no use; our steel-iron rails will never compete with Bessemer steel. You must come and look for yourself." He might say that Sir John Brown, although perhaps one of the most go-ahead men of his time, was rather bitten by the feeling that existed amongst all the steel-makers in Sheffield at that time, and he thought that when they saw what their position was they would hardly wonder at it. The Jessops, the Turtons, the Sandersons, and the Butchers, large steel-makers, had carried on a very successful trade for many years; they had amassed considerable fortunes, and had laid out a good deal of money in erecting converting furnaces and melting furnaces for making cast steel. It was a beautiful trade, and they succeeded in making a most excellent article—as good an article as was made at the present time, although he was speaking of a period thirty years ago. Such a trade could scarcely be found in England, and one considerable advantage which commercial men would recognise was, that they could have twelve months' credit for the material they used. They would not wonder, therefore, that those gentlemen were very uneasy when Mr. Bessemer came and said, "Now, I can give you as good a thing for £20 as you are charging £40 for, and you can make it in little or no time, and you will not require to keep the stocks you now have." There were many other advantages which Mr. Bessemer laid before them. They pooh-poohed the matter at the time, and turned their faces away from it as much as possible, and it was reserved for Mr. Brown and himself to recognise the importance of it. As Sir Henry Bessemer had told them, they immediately took out a license, and Mr. Bessemer was kind enough to make them a present of £1000 out of their first payment. They carried on the Bessemer steel trade for some time; they made steel rails and tested them, and they seemed to be everything that could possibly be wished. But there was something more to be done than simply making rails; there was also the introduction of them. There were many eminent engineers who would not look at them. One of the most practical engineers who used to sit at that Board, and who, he was orry to say, had died during the past twelve months, was induced

to go and look at the rails, and they showed him experiments with them. They dropped weights upon them, but it was of no use. "No, no," he said; "I really am astonished that you should think I am such a fool. The idea of any man laying down a steel rail and running an engine over it! It altogether astonishes me that anybody should be so foolish. No, Mr. Brown; I did think better of you than that; and while I am connected with the railway interest, no steel rail shall ever go on any line I have anything to do with." That, they would admit, was rather a wet blanket for them. He thought at first that they were likely to do pretty well in their immediate neighbourhood. However, they had to go farther afield, and they fortunately met with a man—a man whom he considered to be one of the first practical engineers in England (though perhaps they might say that it was rather an Irishism)—he meant Mr. Fisher, of the Taff Vale Railway in Wales. They showed him all that they had shown to the other gentlemen, and he said, "Send me some rails down; they will suit our work." And so they sent their steel rails right into the middle of what they might call the iron-rail district. Mr. Fisher was perfectly satisfied with them, and it was through his intervention, and through his giving them such a start, that they were able to push the trade in the way that they did. Their first price, as the President had said, was £23 or £22, 10s.; but they sold many thousands of tons at £18, 10s. and £19.

He thought it was the President or Sir Henry Bessemer—he did not know which—who seemed to intimate, or, in fact, had absolutely said, that the rails did not then cost them much more than they were costing now. He thought it would not be fair to the present manufacturers that that should go uncontradicted. They cost, he should think, more than twice as much as they were costing now, if not three times as much, because they had not, to begin with, such magnificent material to deal with in making the Bessemer metal. They had not such good pig iron; they were dependent principally at that time upon the Cleator and the Cumberland iron, and they put in a considerable quantity of Swedish iron. Then, again, they had not the knowledge of the use of manganese; the spiegeleisen that they got was very inferior, and they had to supplement it with an iron

from America called Franklinite; but neither the main bulk of their iron, nor the material that they put in to carbonise it, was anything like so good as the material that was now used. The result of all this was that the ingots, when they were made, did not work anything like so well as they worked now. It would not have been possible to roll the rails off in the way that they were rolled off now. They therefore made them 12 or 14 inches square, hammered them down to 6 inches, and then allowed them to cool, chipped out every possible defect they could find, and then re-rolled them into rails. Of course, the weights they made were very much less, for he believed they only rolled 12-foot rails in one length. Therefore, of course, the waste was much greater, the wages were higher, the difficulty of producing the proper quality of pig iron was very much more, and, of course, the cost was proportionately high. They went on with that trade, he thought, until about 1867, or rather longer; and then they began to have opposition from other places, and eventually they were compelled, in consequence of the greater advantages of making them on the coast, to give up the trade of making rails entirely. However, they were not going to give up the Bessemer process because they had to give up making Bessemer rails. They continued, and they continued now, to make tires, and axles, and plates of that valuable material; and in the manufacture of the steel-faced armour-plates which Sir Henry Bessemer had alluded to, they never made them without using Bessemer metal. Thus they would see that, although their rail trade had left them, they still continued to use Bessemer steel; and he trusted that, as long as he was connected with the company of Sir John Brown & Co., that beautiful process (for it certainly was one of the most beautiful processes ever seen) would never cease to be used at the Atlas Works. Thanking them again for their kindness to himself, he would conclude his remarks, which he trusted they would not think unnecessarily long.

The following paper was read:—

ALLOYS OF NICKEL AND STEEL.

By JAMES RILEY, Glasgow.

Some months ago I was asked to examine some specimens of manufactures of various alloys of nickel and iron. The British patents obtained for these manufactures had previously been submitted to me, but their consideration had not caused me to feel much interest in them. When, however, at the request of my friends, I examined the products themselves, my interest was much excited, and, with the consent of my directors, I entered on a course of investigations regarding these alloys which is still in progress. I fear that the paper I have been able to prepare must be considered premature, and perhaps incomplete and disappointing; but since I was honoured by the request of the Council to prepare this paper, I have done my utmost to push our investigations to a conclusion. With the able assistance of my colleagues, Messrs. Dick and Packer, this has been so far accomplished, that I am now in a position to submit for your consideration some interesting facts, which I think will probably have a great and lasting effect on the manufacture of steel and its various applications.

In commencing our investigations, it was arranged that before attempting the manufacture of nickel steel ourselves, a few ingots should be sent to us for treatment and examination. These ingots were of comparatively small size, having been cast from crucibles. They were 4½ inches square, and contained 3 per cent., 5 per cent., and 25 per cent. of nickel respectively.

Samples of plates and bars from these ingots are before you, but it is not necessary to give you details of the tests applied to them, as the results of them will be embodied in my later remarks.

Some time after the conclusion of these tests, a visit to the works in France was arranged to admit of our seeing the process of manufacture, and the degree of certainty with which the desired products could be obtained from the crucible. This was demon-

strated to our entire satisfaction, a number of casts being made, the composition being varied at will, and the qualities and properties of the metal being indicated beforehand. Samples of these casts were brought to our works and tested.

Subsequently, the patentee visited our works, and charges were made which showed that the composition of the metal can be as effectually controlled in the open-hearth furnace as in the crucible.

I have thus briefly sketched the history of our connection with this new alloy, and will now proceed to state the results we have obtained, and the conclusions at which we have arrived.

The alloy can be made in any good open-hearth furnace, working at a fairly good heat. The charge can be made in as short a time as an ordinary "scrap" charge of steel—say about seven hours. Its working demands no extraordinary care; in fact, not so much as is required in working many other kinds of charges, the composition of the resulting steel being easily and definitely controlled. No special arrangements are required for casting, the ordinary ladles and moulds being sufficient. If the charge is properly worked, nearly all the nickel will be found in the steel —almost none is lost in the slag, being in this respect widely different from charges of chrome steel.

The steel is steady in the mould, it is more fluid and thinner than ordinary steel, it sets more rapidly, and it appears to be thoroughly homogeneous. The ingots are clean and smooth in appearance on the outside, but those richest in nickel are a little more "piped" than are ingots of ordinary mild steel. There is less liquation of the metalloids in these ingots, so that liability to serious troubles from this cause is much reduced. Any scrap produced in the subsequent operations of hammering, rolling, shearing, &c., can be remelted in making another charge without loss of nickel. The importance of this fact will be at once appreciated, especially by users of articles made of this metal, seeing that scrap and old articles will have a value for remelting in proportion to their contents of nickel.

No extraordinary care is required when reheating the ingots for hammering or rolling. They will stand quite as much heat as ingots having equal contents of carbon but no nickel, except perhaps in the case of steel containing over 25 per cent. of nickel,

when the heat should be kept a little lower, and more care taken in forging.

If the steel has been properly made, and is of correct composition, it will hammer and roll well, whether it contains little or much nickel; but it is possible to make it of such poor quality in other respects that it will crack badly in working, as is the case with ordinary steel.

In endeavouring to obtain a correct idea of the value or utility of alloys of nickel and iron or steel, we shall find it of use to consider their behaviour under tensile and other mechanical tests, and if these were sufficiently numerous our task would not be a very difficult one.

If it be remembered, however, that in the composition of nickel steel we have present nickel, manganese, and iron, with carbon, silicon, sulphur, and phosphorus, and that even a very small difference in the contents of some of these has a considerable influence on the character of the alloy, it will be evident that several series of tests (involving a very large number of separate experiments) are necessary to a full investigation. For instance, we all know the effect of very small increments of carbon in steel; hence to estimate correctly the influence of the addition of nickel, the carbon (as well as manganese and other contents) should remain constant; then that the contents of nickel should be constant and the carbon, &c., varied; and further, that the subsequent treatment of all the products should be identical in every particular. I have not been able to carry out such an elaborate series of tests, but I beg to submit a few test results which will no doubt be of service at this time.

In Table No. 1 there are several points of interest which it is desirable to notice.

1st, In No. 6 test the carbon present (0·22) is low enough to enable us to make comparison with ordinary mild steel, which would give (when annealed) results about as follows:—E.L. 16 tons, B.S. 30 tons, extension 23 per cent. on 8 inches, and contraction of area 48 per cent. Therefore in this case the addition of 4·7 per cent of nickel has raised the E.L. from 16 to 28 tons, and the B.S. from 30 to 40·6 tons, without impairing the elongation or contraction of area to any noticeable extent. In No. 3 test somewhat similar results are found, with an addition

No. I.—TESTS OF STEEL WITH VARYING CONTENTS OF NICKEL.

Mark.	Composition per Cent.			Tensile Tests as Cast.					Tensile Tests as Cast and Annealed.					Tensile Tests as Rolled.					Tensile Tests as Rolled and Annealed.					Remarks.
	Ni.	C.	Mn.	E. L.	B. S.	Extension per cent. in		C. A.	E. L.	B. S.	Extension per cent. in		C. A.	E. L.	B. S.	Extension per cent. in		C. A.	E. L.	B. S.	Extension per cent. in		C. A.	
						8in.	4 in.				8in.	4 in.				8 in.	4 in.				8 in.	4 in.		
	Per cent.	Per cent.	Per cent.	Tons.	Tons.			Per cent.	Tons.	Tons.			Per cent.	Tons.	Tons.			Per cent.	Tons.	Tons.			Per cent.	
1.	1·0	·42	·58	Test-piece defective.					27·3	54·6	...	1·5	9·5	32·1	57·6	...	11·0	24·0	30·1	55·1	...	18·7	45·0	
2.	2·0	·90	·50	Too hard to machine with musket-steel. Makes a fine tool tempered at dull red in boiling water.																				
3.	3·0	·35	·57	19·8	34·9	...	2·5	5·6	24·0	34·9	...	2·5	9·0	31·4	51·0	...	20·3	37·0	28·0	48·5	...	20·3	42·0	
4.	3·0	·60	·26	...	...	...	...	...	...	...	...	...	...	29·4	51·5	9·0	10·1	9·0	30·3	42·9	7·5	9·0	12·0	
5.	4·0	·85	·50	Too hard to machine with musket-steel. Makes a fine tool tempered at dull red in boiling water.																				
6.	4·7	·22	·23	...	...	...	...	...	...	...	...	...	...	25·1	40·5	17·75	23·4	42·0	28·0	40·6	20·0	25·0	44·8	Average reduced by one piece, giving low result.
7.	5·0	·30	·30	...	...	...	...	...	...	...	...	...	...	30·0	46·4	10·0	12·5	22·5	28·0	42·6	15·0	17·5	18·5	
8.	5·0	·50	·34	...	...	...	...	...	...	...	...	...	...	31·1	52·0	14·0	15·6	14·0	32·5	46·8	13·5	14·0	17·0	
9.	10·0	·50	·50	Too hard to machine. Makes a good cutting tool when tempered in cold air-blast.																				
10.	25·0	·27	·85	...	...	...	...	...	...	...	...	...	...	38·2	51·4	10·5	11·7	...	12·75	45·8	29·0	30·0	28·6	
11.	25·0	·82	·52	...	...	...	...	...	...	...	...	...	...	22·0	47·6	43·5	47·6	60·0	15·1	42·1	40·0	45·3	43·6	
12.	49·4	·35	·57	...	...	...	...	...	...	...	...	...	...	20·5	37·4	...	12·0	24·0	21·0	37·0	...	20·0	29·0	

E.L.=Elastic limit. B.S.=Breaking strain. C.A.=Contraction of area.

of only 3 per cent. of nickel, combined with an increase of the carbon to 0·35 per cent.

2nd, In Nos. 2 and 5 tests there is extreme hardness, due in part to the large quantity of carbon present, but also to the presence of nickel in addition. In No. 9 test, with the carbon very much reduced, this characteristic of hardness is intensified by the increase of nickel to 10 per cent.

This quality of hardness obtains as the nickel is increased, until about 20 per cent. is reached, when a change takes place, and successive additions of nickel tend to make the steel softer and more ductile, and even to neutralise the influence of carbon, as is shown in No. 11 test, in which there is 25 per cent. of nickel and 0·82 of carbon. In this matter of hardness, due to increased increments of nickel, there is some resemblance to manganese steel, as described in Mr. Hadfield's admirable paper; but I am glad to be able to state that before the region of extreme difficulty of machining is reached we have qualities of nickel steel available which will be of the utmost value for a very large number of purposes.

3rd, In the 25 per cent. nickel steel there are some peculiar and remarkable properties. In the unannealed specimen, the B.S. is high and the E.L. moderately so, but in the annealed piece, while the B.S. remains good, the E.L. is very greatly reduced, down to one-third of the B.S. Again, in both cases, the ductility as shown by the extension before fracture is marvellous, reaching 40 per cent. in 8 inches. Another feature (clearly brought out in tests Nos. 10 and 11, most in No. 10, by the small contraction of area) is that this elongation is nearly uniform throughout the piece.

Before leaving this class of tests, I may state that a very large series of hardening and tempering tests, which I have had made, but which I am not prepared to submit at present, show the possibility of very largely raising the B.S. and E.L., and the hardness of these alloys. We have tested pieces up to 87 tons B.S. with 52 tons E.L.; but there is a piece before you—furnished by the patentee—which was tested by us, and gave B.S. 95·6 tons, E.L. 54 tons, extension in 4 inches 9·37 per cent., contraction of area 49·2 per cent. Two similar pieces, tested by Mr. Kirkaldy, gave B.S. 94·18 and 93·86 tons, E.L. 52·01 and 53·92 tons, extension 7·8 and 8·2 per cent., and contraction of area 52·4 and 50 per cent. respectively.

Permit me now to invite your attention to Table No. 2, which gives results of torsion tests.

In the right-hand column, headed "Remarks," is given the number of sample or test in Table No. 1, for reference as to tensile, strength, &c.

The torsion tests have been made on the steel in the condition in which it left the hammer, and also after having been annealed.

I have arranged both classes in what we consider order of merit, having regard to all the three qualities of B.S., E.L., and ductility, as shown by number of twists borne by each. It is satisfactory to find that to obtain the best results it is not necessary to use the steels rich in nickel, as only 1 per cent. is present in that which stands first in both classes.

There are several interesting points in this table to which I would ask your consideration. 1*st*, At the foot of it I give results of torsional tests on Siemens steel. Nos. 7 and 8 are tests of the same steel annealed and unannealed, having a tensile strength of 47·2 and 50·4 tons respectively. A comparison of these two shows a very slight improvement in ductility due to the annealing. Now compare them with No. 9, which is a test of ordinary mild steel of 30 tons tensile strength, and it will, I think, be concluded that it would be better to sacrifice some of the ductility shown by the greater number of twists, in order to obtain some of the greater strength shown in the higher E.L. and B.S. of Nos. 7 and 8. It has become common to order propeller and other shafts of mild steel, but I am inclined to the opinion that their resistance to both stress and wear would be increased by the use of stronger steel, while still leaving an ample margin of ductility. But this is incidental.

2*nd*, I would ask you next to compare the results obtained with the ordinary steel with those of the nickel steel, and I think there will be no hesitation in deciding that there will be a very great advantage gained by the use of the latter—advantage either in reduction of scantling or in increased strength and ductility.

3*rd*, It is interesting to notice how very closely this series of tests confirms those in Table No. 1, the E.L. and B.S. in both annealed and unannealed samples corresponding, and having the same relation to each other in both systems of tests, while the

No. II.—TORSION TESTS.

Mark.	Number of Twists in 3-inch Length.	Diameter of Bar 1 inch. Lever 1 foot long. Weight in lbs.		Condition.	Composition per Cent.			Remarks.
		Elastic Limit.	Breaking Strain.		Ni.	C.	Mn.	
1.	$1\frac{7}{8}$	857	1849	As hammered.	1·0	0·42	0·58	No. 1 Sample in No. 1 Table (unannealed).
2.	$2\frac{1}{8}$	677	1507	,,	5·0	0·30	0·30	No. 7 ,, ,, ,, ,,
3.	$1\frac{3}{4}$	665	1729	,,	3·0	0·35	0·57	No. 3 ,, ,, ,, ,,
4.	$1\frac{7}{8}$	621	1493	,,	4·7	0·22	0·23	No. 6 ,, ,, ,, ,,
5.	$2\frac{5}{8}$	553	1554	,,	50·0	0·35	...	
6.	3	510	1950	,,	25·0	0·27	0·85	No. 10 ,, ,, ,, ,,
1A.	$1\frac{7}{8}$	697	1809	Annealed.	1·0	0·42	0·58	No. 1 ,, ,, ,, (annealed).
2A.	$2\frac{3}{8}$	653	1485	,,	5·0	0·30	0·30	No. 7 ,, ,, ,, ,,
4A.	$2\frac{5}{8}$	652	1443	,,	4·7	0·22	0·23	No. 6 ,, ,, ,, ,,
6A.	5	360	2100	,,	25·0	0·27	0·85	No. 10 ,, ,, ,, ,,
7.	$1\frac{15}{16}$	601	1689	,,	...	0·51	...	47·2 tons per square inch, Siemens steel.
8.	$1\frac{9}{16}$	601	1697	As hammered.	...	0·51	...	50·4 ,, ,, ,, ,,
9.	$3\frac{1}{8}$	445	1229	,,	...	...	...	30·1 ,, ,, ,, ,,

number of twists corresponds closely to the ductility as measured by extension in the tensile tests.

There are a few other properties of these alloys to which I will briefly refer. The specific gravity of nickel is given as 8·66 (we make it 8·86); that of ferro-nickel, if 25 per cent. nickel, 8·08; that of 10 per cent. nickel, 7·866; that of 5 per cent. nickel, 7·846; while the mean of our results of hammered steel is 7·84.

The whole of the series of nickel steels up to 50 per cent. nickel take a good polish and finish, with a good surface, the colour being lighter with the increased additions of nickel.

In the very important matter of corrodibility, it is with the greatest satisfaction I can state that the steels rich in nickel are practically non-corrodible, and that those poor in nickel are much better than other steels in this respect. Thus some experiments we have made show that, as compared with mild steel of 0·18 carbon, 5 per cent. nickel steel corrodes in the ratio of 10 to 12, and, as compared with steel having 0·40 carbon, with 1·6 chromium, in that of 10 to 15. In the case of 25 per cent. nickel steel, these ratios are as 10 is to 870, and 10 to 1160 respectively. These results were obtained by immersion of samples of the different steels in Abel's corrosive liquid, and the results confirmed by subsequent immersion in water acidified by hydrochloric acid. Some samples of the richer nickel steels which have been lying exposed to the atmosphere for several weeks still show an untarnished fracture.

The alloys up to 5 per cent. of nickel can be machined with moderate ease; beyond that strength they are more difficult to machine. The poorer ones stand punching exceedingly well, both as rolled and after annealing. The punch-holes can be put as close together as $\frac{1}{8}$ inch without the metal showing any signs of cracking.

The 1 per cent. nickel steel welds fairly well, but this quality deteriorates with each addition of nickel.

The poorer alloys do not show any lustre, but the richer ones have a lustrous appearance when the scale is removed.

I do not think I have anything more to add as to the properties and qualities of these alloys, but it may be interesting to state the theory held by the inventors regarding their formation. They state that they adopt M. Chernoff's view of steel—that it is

composed of crystals of metallic iron, cemented together by carbide of iron—and they account for the extra strength given to steel by nickel, by its alloying with this carbide of iron to form a stronger "cement;" that the space between the crystals of iron is thus more completely filled, and the cohesion between them rendered much more powerful; that the points of solidification of the cement and crystals are nearer, producing or maintaining a more intimate interweaving of the elements; that their process of manufacture is necessary to cause the nickel to enter into combination and produce a homogeneous alloy, as without it there would only be formed a mechanical mixture, not possessing homogeneity, malleability, or ductility.

In concluding, I may be permitted to indicate some of the possible uses to which these alloys may be applied. It requires no powerful imagination to conjure up a most bewildering number of applications for which they are available. I find some difficulty in not becoming enthusiastic on the point, for in the wide range of properties or qualities possessed by these alloys, it really seems as if any conceivable demand could be met and satisfied.

Of the richer alloys I do not intend to speak at any length, but would just remark that in the immense field covered by what are termed the "Metal Trades," innumerable applications will be found for which they are suitable. Some specimens of these applications are before you.

Of the 25 per cent. nickel steel I would remark, that with its peculiar properties of high B.S., great ductility, and *comparatively* low E.L., it is extremely well adapted for all operations involving considerable deformation—for instance, for deep stamping and flanging—whilst its non-corrodibility will render it invaluable for a great number of purposes.

This quality of non-corrodibility, considered together with its strength, both elastic and ultimate, when unannealed, will render it specially useful in all cases where the cost of metal is of minor importance when contrasted with the cost of labour to be expended upon it, or its use for special purposes: illustrations of these may be found in all small and special type boilers, in locomotive and other fire-boxes, and in the hulls of torpedo and other similar vessels, where lightness and strength with non-corrodibility are of vital importance.

In the region between 25 per cent. and say 5 per cent. nickel we have an abundance of possibilities as yet comparatively unknown, in which I expect will be found materials for tool-steel equal, if not superior, to anything at present known.

But it is when we get to the alloys of 5 per cent. and under that I feel most interested, and I think most of you will sympathise with that feeling.

I have already incidentally referred to the advantages the marine engineer will obtain by the use of these qualities for the shafts and other forgings used in his structures. I would now point to the suitability of these lower alloys to the other portions of his work. It is well known—it has been frequently stated by my friend Mr. Parker and others—that the recent advances in marine engineering, rendered possible by the use of high-pressed steam, could not have been effected if it had not been that a metal superior to wrought iron was put at the engineer's disposal. Conceive then of the possibilities now presented when a metal like No. 6 in the Table No. 1 is at his disposal, having when annealed an ultimate strength of 30 per cent. and elastic limit of 60 or 70 per cent. higher than those of mild steel, with a nearly equal ductility, and the valuable quality added of less liability to corrosion. He may at once greatly reduce his scantlings for present pressures, and get rid of many difficulties of construction, or he may avail himself of the increased strength to provide for still higher pressures.

It will also be seen that these metals are equally important to the shipbuilder and to the civil engineer. This is strongly brought out in considering the immense advantage to be derived from their use in large structures. Think for a moment of this in connection with the erection of the Forth Bridge or of the Eiffel Tower. If the engineers of those stupendous structures had had at their disposal a metal of 40 tons strength and 28 tons elastic limit, instead of 30 tons strength and 17 tons elastic limit in the one case, and say 22 tons strength and 14 to 16 tons elastic limit in the other, how many difficulties would have been reduced in magnitude as the weight of materials was reduced; the Forth Bridge would have become even more light and airy, and the Tower more net-like and graceful than they are at present.

Then, as regards the requirements of the military engineer, I am inclined to state firmly that there has not yet been placed at his disposal materials so well adapted to his purposes—whether of armour or of armament—as those I have now brought under your notice.

In what may be called their natural condition these alloys have many properties which will commend them for these purposes, and when the best method of treatment, by hardening or tempering, has been arrived at, I believe that their qualities for armour will be unsurpassed.

In conclusion, I have to repeat what I stated in commencing, that I regret I have not been in a position to give you as much information about these alloys as I could have wished, but I have done my best in the time at my disposal, and in the circumstances in which I found myself.

DISCUSSION.

Mr. J. F. HALL (Sheffield) said that it was with very extraordinary feelings that he rose to discuss the paper. When he saw the paper on the list he certainly was a little bit staggered; but when he came to think that Mr. Riley might very readily, without his knowledge, be working in exactly the same directions that he himself had been doing for some considerable time, he thought perhaps it was not so curious as it at first appeared. They had all to congratulate Mr. Riley on the very able manner in which he had put before them the facts with regard to nickel. It was what he called a very modest paper, because it did not refer so much to inventions that Mr. Riley himself had made as to those of others. He had only got the paper last night; he had therefore had very little time to investigate the matters referred to with regard to the British patents taken out by Mons. Marbeau. Some fifteen months ago he himself had had granted to him letters-patent for the use of nickel in steel, from 2½ per cent. to 50 per cent. Whether that patent had been infringed by M. Marbeau, or whether he had infringed M. Marbeau's patent, was not a question to be discussed there. He might say he had carried out a very large series of experiments with regard to nickel in all the proportions given by Mr. Riley in his valuable paper, and in many others. He had, indeed, gone further than that. He had at the present time many articles at work in different parts of the world, and for different reasons, made from nickel steel containing from 2½ per cent. to 50 per cent. of nickel. He had had no intention whatever of bringing this subject up, and should certainly not have done so at the present time if it had not been for this paper; for, although he had made now some thousands of experiments, he did not consider the subject to be thoroughly thrashed out. There was a great deal in this that required very careful attention and watching. Some twelve months ago he applied nickel steel with a large proportion of nickel to gun-barrels, and as an experiment he had some made for ordinary 12-bore fowling-pieces. He presented a pair of those barrels fitted to a gun made by a very eminent firm of gun-makers

in London, Messrs. Holland & Holland, of New Bond Street, to the chairman of the company he represented (Mr. William Jessop). Mr. Jessop shot with that gun during the greater part of last season with the most satisfactory results. Previously, they had made a barrel which was tested by Messrs. Holland & Holland to destruction. The ordinary test of a gun-barrel for a 12-bore gun was something like this: in practice they use three drachms of powder and one ounce of shot; and in testing they went up to four or five drachms of powder and an ounce and a half of shot. Nine tests in all were carried out; the ninth test contained fifteen drachms of powder, three and a half ounces of shot, and double wadding. At that charge the gun-barrel burst, but it did not burst in the real sense of the word, for it was merely opened and laid out flat. The maker of that gun, who had probably made more high-class guns than any other living person, informed the speaker that he never in all his experience had seen or could imagine such a piece of material. Some nine months ago (he did not think the owners knew it), out of a series of four propeller-blades, he had made one from this nickel steel. He was still awaiting the results, to compare the corrosion of that blade with the corrosion of the others, which were of ordinary steel.' Many small articles similar to those which Mr. Riley had exhibited in the room he had also made, and had now at work in many places. He had also made wire, but he must admit that he had not drawn any wire down, or tried to draw it down, as fine as some of that shown on the table by Mr. Riley, which, he had no doubt, might be available, as a gentleman said just now, instead of cotton to sew buttons on with, it was so very thin and strong. More than twelve months ago his firm was honoured with an order from the Government for an experimental 6-inch gun. That gun was now in course of construction, and was partly finished. It was made of nickel steel; and if it had to be fired, he should not hesitate for one moment to pull the string when it was loaded with its full proof charge. The meeting would therefore see that, although Mr. Riley had brought this valuable paper before them (he did not wish for one moment to detract from anything Mr. Riley had said), there were other people besides Mr. Riley and his friends who had been working in this direction. It was said in the morning,

he thought by their American friend, Mr. Hewitt, that this Society was a medium for sending out information to the whole world, which their American cousins were the first to adopt. It was with feelings of that kind that he thought this subject should be more thoroughly perfected and brought to a focus before any paper on it was read, and that accounted for his silence during the time he had been making these experiments. His first experiments with nickel steel were made years ago, and they were made with very small proportions. It was only within the last two years that he had begun experimenting with over 2 per cent. Mr. Riley had given some very extraordinary results, and the President had also given them the result of 94 tons tensile strain and 8 per cent. elongation. There were others of over 90 tons tensile strain, but there was not one that came up to the test that he made nearly twelve months ago, when he got 97 tons tensile strain, and seven and some odd decimal per cent. elongation. He had not been able to beat that yet, and he thought most of them would agree that they ought to be satisfied when they got so much.

Mr. WM. JENKINS (Consett) asked Mr. Riley if he could give some idea of the price at which nickel steel could be manufactured.

Mr. JAMES RILEY reminded Mr. Jenkins that the President had laid down a very wholesome rule that morning, which was an old rule of the Institute, namely, that they had nothing to do there with commercial subjects, and he could not at that moment answer that question.

Mr. G. J. SNELUS, F.R.S., said he would like to add one or two words to the discussion, and first of all he would congratulate the last speaker, who, although he had spoken last, appeared to come first. He was very proud indeed that at all events there seemed some possibility that this discovery would redound partly to the credit of their own country. He must congratulate Mr. Riley also upon the elaborate series of experiments that he had carried out in so short a time; but he would like to point out to members present that they had neglected some-

thing which nature had long wanted to teach them. Shakespeare told them that they might find "tongues in trees, sermons in stones, books in the running brooks, and good in everything," and those who had studied meteorites appeared to have overlooked the fact that the metallic meteorites consisted largely of alloys of iron and nickel. It was a remarkable fact that most of the metallic bodies that fell to the earth consisted of that alloy which they were now for the first time becoming acquainted with, as produced by themselves. Therein they seemed to have overlooked the teaching of nature in regard to these metallic alloys. He was very glad that they were now finding out the value of that product, and he certainly thought that what they had heard that day would in the future produce enormous results. He should like, also, to call attention to the explanation which Mr. Riley had given, or rather his reference to Chernoff's explanation, as to the greater tensile strength of the alloy, and to what that greater strength was due. He did not quite agree with Chernoff's explanation. He thought the reasons why alloys of nickel and iron would bear a greater tensile strain, and give greater elongation, than the alloys of iron with which they had hitherto been acquainted was, that these alloys were more homogeneous. The alloys of iron which they had hitherto had to deal with were not homogeneous, and were very unsound, and he also believed that, in testing, the reason why a plate broke at a given point was, that the weakest point in that piece of 8 inches was found, and the weakest point being found, the plate began to give way at that point, and often the rupture took place locally, and the extension was only over a particular area. Mr. Riley had called attention to the remarkable fact that the extension in one of these samples was uniform over the whole length, which seemed to point to the fact that the material was homogeneous over the whole of its length, and he accounted for that fact by the nickel being more allied in its nature to iron than any of the other metals which they had hitherto attempted to alloy with it; and, as he said, nature had been all along attempting to teach them that by throwing these bombs on to our earth from the skies, and they had all along neglected it. He was quite ashamed that he himself had overlooked nature's teaching.

Mr. EDWARD RILEY said that nickel, as presented to them commercially, was a very impure material, containing silicon, and frequently copper, and perhaps other metals, there being perhaps not more than 97 per cent. of pure metal, and its relation was somewhat that of cast iron to wrought iron. This seemed to him to be a difficulty. He was not aware that nickel had ever been used in the blast furnace. No doubt it would alloy readily with the pig iron made, and that would be the ultimate form in which to use it, in the same way that they used chrome iron and spiegeleisen. Its cost at present seemed to him to present a serious detriment to its use. He had asked his friend on the right (Mr. Hall), and he told him the cost was about 2s. per lb., which was somewhere about his own idea; and he thought his friend, Mr. James Riley, would tell him that that was a serious obstacle to its use at present. Minerals of nickel did not seem, like the minerals of chrome and manganese, to present themselves in a suitable form for use in the blast furnace. That was rather an unfortunate feature. He did not himself recollect any mineral of nickel which was found in any quantity that could be used in the blast furnace, because that was the practical point that one must come to eventually. The New Caledonian nickel was a very poor mineral, containing large quantities of silicate of magnesia. Then there were other descriptions of nickel, as the kupfernickel, which was a sulphide and arsenide, a very impracticable form to use in a blast furnace. Of course, he was looking at it rather, no doubt, in a practical sense, but he thought all practical men would agree with him, that if they were to use alloys, they should use them very much in the same way that chrome iron and spiegeleisen were used in the blast furnace.

Sir LOWTHIAN BELL, F.R.S., said he had very few words to say upon the subject. Mr. E. Riley had spoken of the difficulty of speaking with any precision with regard to the effect of nickel upon iron, and he grounded that difficulty on the fact that nickel, as they knew it, contained other metals, copper and so forth. That did not appear to him to be a serious objection, because all it amounted to was this, that in employing a substance which had been described as nickel, they used what was in point of fact an

alloy of nickel and something else; but if it produced the effect upon steel that was claimed for it by Mr. Hall and the author of the paper, it did not appear to him to be of much importance whether it was alloyed with 3 per cent. of copper or not. With regard to the reproach which had been addressed to the science of metallurgy by Mr. Snelus for not having inferred that nickel might improve iron because it occurred in meteoric stones which had been falling on the face of the globe for many thousands of years, he failed to discover why on that account this metal necessarily ought to have great value as an alloy of iron. He never heard it pretended that meteoric stones possessed great tensile strength. On the contrary, he believed many of them could be pounded in a mortar.

Mr. SNELUS said that the meteoric stones were different from the metallic meteorites.

Sir LOWTHIAN BELL said he was not including all the metallic meteorites in his observation.

Mr. SNELUS: They are perfectly malleable.

Sir LOWTHIAN BELL said he would not press that objection. He was not sure that Mr. E. Riley was right in considering that the blast furnace was the proper place for alloying iron with an expensive material like nickel, for they knew how large the waste was in manganese when making ferro-manganese, and possibly the same might prove to be the case with nickel, which was worth, he believed, something like 1s. 6d. or 2s. per lb. He had no information on the subject, and only suggested the possibility of such a loss as the one he had named occurring.

Mr. W. H. WHITE (Admiralty) said that he had only had an opportunity of seeing the paper within the last hour, and had glanced hastily through it. As one who had to do with the use of steel very largely, he might say that he quite endorsed what Mr. Hall and other speakers had said as to the interest and value of these experiments. There were certain points, from the user's point of view,

which occurred to him on hastily reading this paper. Other alloys of steel had been produced which possessed very admirable qualities, but which were very nearly unworkable in the ordinary operations of the machine-shop or the shipyard. It was perfectly clear from Mr. Riley's table that there were some of these alloys which might be placed in the same category as unworkable; but he understood—and if he was wrong Mr. Riley would correct him—that the specimens with 5 per cent. of nickel, for which tests were given in Table I., were workable, and could be readily punched or machined. There was one other point which he thought was of great importance. Could engineers and shipbuilders, in dealing with composite riveted structures (such as boilers or the hulls of ships) depend upon getting rivets which would be workable and trustworthy, and of which the strength should be adequate in proportion to the high tensile strength of plates of the new material that would have to be combined? It was now a good many years since the Landore Company made many experiments with high-tension steels. They were good enough to carry out some suggestions of his own in connection with those experiments; and there they found that the limit of the strength of steel suited to ship-work was not determined so much by the quality of the steel that might be used in the form of plates, as by the quality of the rivet-steel suitable for employment in combining plates of high tensile strength. He would be glad, therefore, if Mr. Riley would tell them whether his experience went to show that with nickel steel they could get rivets which would be workable and trustworthy, and would have strength in proportion to the plates with which they would have to be combined. There was another thing from the user's side. It was not always possible, nor, in fact, desirable, to make the full reductions of scantlings that might be made on the basis of providing sufficient general structural strengths in ships or other structures. For example, in passing from iron of the quality which was formerly used in the Admiralty service to mild steel such as was now used, the reductions in scantlings in many parts of the structure, were necessarily made much less than would have been warranted by a simple consideration of the relative strengths of iron and steel. Although they were dealing with a stronger material, other con-

siderations came in to limit savings in scantlings and weights. The same thing would be true, clearly, of these nickel steels. As he understood, this was not the place to dwell upon the commercial side of the matter. But the user necessarily had to think what he paid for his material in relation to the results which he got. As to non-corrodibility, they had long been in possession of alloys which could be used as substitutes for steel, particularly for torpedo-boat construction. These alloys, while possessing durability and non-corrodibility, would also give the strength of hull desired. But these alloys had not found general favour, for a very simple reason. He was not treading upon any official secrets when he said that it had not paid to use these alloys instead of steel. It was cheaper to use mild steel, and with that material the reductions in scantlings might be carried further than they were carried, were it not for the fact that experience had fixed a practical limit of thinness, imposed by the conditions of service and knocking about which torpedo-boats had to fulfil. It was cheaper, in fact, to use ordinary steel for such boats, and to paint their bottoms frequently, than to use a non-corrodible metal. He was not in the least suggesting that the production of materials having the qualities described in the paper might not be beyond price for certain purposes. That was not his point. Looking at the matter from the point of view of the shipbuilder, the marine engineer, or the civil engineer, there were other considerations which must come in. They did not always use what was absolutely the best, but what was best when they took into account what was commercially profitable and sufficient for the purpose that they had in view. He might add one word more upon the armour question. During the last two years there had been a series of experiments made by the Admiralty, and in carrying out these experiments they had been helped a great deal by the enterprise of British steel-makers. He spoke in that room a very short time ago, in the course of a discussion which was then proceeding on this question, and he thought there could be no harm in his repeating before the Iron and Steel Institute what he then said. It had been proved beyond question that all that had been said in the press and elsewhere as to the inferior position occupied by English steel-makers in the production of steel armour

was not true. The finest steel plates that had ever been fired at, he believed, were those of English steel-makers which had been fired at in this country during the past year. He might be permitted to state that one plate included in the series of experiments which the Admiralty conducted had the very qualities, so far as manufacture went, which were represented in the armour-plate now before them. The maker of that armour-plate had long maintained that it was possible by chemical processes, and by treatment, to obtain results equivalent to those ordinarily obtained by mechanical work. This maker had the courage of his opinions, and he sent the Admiralty a plate, which, looked at from one side, might not be regarded as wholly successful, but looked at from his side as the upholder of a principle, was remarkably successful. The same principle was exemplified in the nickel steel armour-plate exhibited; and without trenching on the commercial side, he might say that if it was possible to produce armour as a mere casting, and to the shapes which they required in ships, whether nickel or any other metal was the alloy which was worked in with the steel, it might be taken for granted that not merely the British Empire, but all those who had to do with war-ships, would be delighted to see it. But before it could be used it must be subjected to a test which was more severe than was represented by the specimen exhibited.

If those who had to do with this nickel alloy would only give the Admiralty an opportunity of firing at a plate corresponding in thickness and size to those which had been fired at in the series of experiments to which he had alluded, he was sure the experiment would be made as soon as circumstances permitted.

Sir BERNHARD SAMUELSON, Bart., M.P., said he had a question to ask Mr. James Riley, and perhaps if the author of the paper could not answer it himself, the gentleman who represented the French patentee might be able to do so. It was as to the effect of nickel as an alloy with cast iron. Gentlemen present were no doubt aware that, for the purpose of the manufacture of many articles by the process of what was called malleableising cast iron, iron was cast in crucibles. He would like to ask whether any experiments had been made by the patentees in reference to

the effect of the addition of nickel to cast iron to be used for the purpose of making castings from the crucible.

Mr. BENJAMIN MARTELL (Lloyd's) said he felt very much indebted to Mr. Riley (speaking from the point of view of one who, as Mr. White had said, had a good deal to do with the use of mild steel) for producing his paper. He could not lose sight of the fact, which had always appeared obvious to him when on any occasion he had had the pleasure of listening to a paper by Mr. Riley or to any of his remarks, that they owed so very much to him, more than to any one else, although perhaps others might have preceded him. It was to Mr. Riley that they owed their thanks for being able to produce mild steel in the construction of mercantile ships in this country. Therefore, anything that that gentleman might bring forward on matters of that kind must be deserving of their very great respect and consideration. He was very pleased to find that Mr. Riley had gone on improving in that beautiful material which he had given them for the construction of ships. It seemed to him that what Mr. Riley suggested, and what was shown by his experiments on that material, was, that he was producing a material infinitely superior to the ordinary mild steel which he introduced to them in the first place when they adopted it for the construction of their ships. There were two things in particular for ship purposes that they wished to attain. The first was to make the elastic limit of steel higher than it was at present. Ship-plate iron, no doubt, had a great advantage in some respects over mild steel. He would not say that the limit of elasticity was greater—it was not greater in proportion than it was in steel—but the scantlings of steel were reduced, so that the tensile strength of the new material should at least be equal to iron, whereas its elastic limit was, in proportion to the thickness, no greater than it was in iron itself, and consequently there was not the advantage in that respect, as regards steel, over the thicker material of iron. They had been enabled, by the production of a material of much greater ultimate tensile strength than iron, comparatively, to reduce the scantlings; and if makers at the same time could raise the elastic limit of steel in relation to iron, they would be doing a very great deal of good. He trusted that Mr. Riley would be able to

extend that limit, and to do so to a material extent. That was a very important point. The next important point was, that it appeared they were approaching a position where they would be able to reduce that great objection—he was sorry to say it was a great objection at the present time, and one liable to be overlooked by careless persons who had to do with the use of that material—of its greater liability, under some circumstances, to corrosion. They had had instances lately of comparatively rapid corrosion, and it was right he should bring the matter forward, because he thought it was better to face those things at once. There was no doubt that, owing to the very superiority of mild steel, of the purer quality, it was more liable to corrosion, if neglected, than the harder and more impure qualities of iron. They found that in actual experience. If they neglected a steel ship, and did not take great care in protecting its bottom by a proper composition, they would find that the deterioration, particularly as regarded the effect of salt water upon the steel, was much greater than it was with regard to iron. This experience, however, was not unusual with regard to some descriptions of iron itself. Where, as in some instances, they used rivets made of Lowmoor iron, or Farnley iron, as purer material it was more liable to corrosion than ordinary ship-plate iron. It was right that that should be forced upon the minds of shipowners, in view of the fact that at the present time, in the Society he represented, they were superintending the building of something like 800,000 tons of shipping, and that 90 per cent. of that was being built of mild steel. It was right that shipowners should have forced upon them the great necessity of protecting the outsides and insides of those ships, in order to prevent the more rapid corrosion than would take place if the vessels were of iron. It was very pleasing to him to find, from what Mr. Riley indicated in the paper, that by the alloy he was about to introduce they would prevent to a considerable extent this corrosion. If Mr. Riley could only accomplish those two points he had referred to to a limited extent—that was, to raise the elastic limit of the material, and at the same time do something to prevent the more rapid corrosion of mild steel, he would have accomplished great good in connection with the building of ships of mild steel. He might say that, more particularly on account of the latter consideration, there

were some shipowners who, in his opinion, were foolish enough to go back to the building of ships of the old, unsatisfactory, and unreliable material of iron, because they said it was more expensive to keep up steel ships owing to their greater corrosion. Of course, as he had told them, it was only necessary to take more care. They had only to properly protect the surfaces, and then they had nothing more to fear with regard to mild steel than they would have with iron, whereas they had a material that was infinitely superior in every respect to the old material of ship-plate iron. Therefore, he congratulated Mr. Riley very much indeed upon the production of his paper. He trusted that it would lead to good results, such as appear to be indicated in the paper, and that they would be able to produce a material combining all those splendid qualities that they had in mild steel, with a greater limit of elasticity, and at the same time a more incorrodible material than they had either in mild steel or in iron.

Mr. PERCY C. GILCHRIST asked whether nickel would replace manganese; that is, could one get an alloy of iron and nickel without any manganese which would work properly? Another point he wished to raise was, could Mr. Riley reduce the carbon (keeping the nickel and manganese as shown in his tables) down to ·1 or ·08 per cent., and would the nickel alloy then work all right, and what tensile strain and elongation would such an alloy possess?

Mr. WILLIAM PARKER (Lloyd's) regretted that he had not had an opportunity of hearing Mr. Riley read his paper. He had, however, been able to glance through it on his way from the City, and he saw that Mr. Riley had mentioned his name in connection with it. When Mr. Riley introduced steel for shipbuilding, and more particularly for marine boiler-making purposes—or rather when he read his first paper on this subject before the Institution of Naval Architects in 1876—as little was thought about his proposals as was now thought of the proposals he had laid before them in the form of nickel steel. Mr. Riley referred to the action that he (Mr. Parker) had taken in connection with the introduction of mild steel, and the advantages that were obtained from the introduction

of that metal. As a matter of fact, shipowners had obtained from the introduction of that mild material an advantage represented by a reduction of 25 per cent. of fuel; and if Mr. Riley could give them a material with 30 per cent. more strength, a corresponding amount of ductility, and a corresponding increase in elastic limit, they might look forward to the shipowners receiving another great boon. He was sure it would be welcomed by the shipowner; and, as far as they at Lloyd's Registry were concerned, they would welcome it, and give to Mr. Riley all the assistance they possibly could to endeavour to make it a success. But they must understand that it was a new material, and that Lloyd's would have to be satisfied of its superior properties. They would have to subject it to very rigid tests, and Mr. Riley would have to make up his mind to comply with the tests before any reduction of scantlings, or corresponding advantages over the material now in use, could be allowed. However, those tests would be made in a public manner; and if this new material was found to possess all the properties mentioned in the paper, and it was shown that it could be worked in the same manner as mild steel, he was sure it would receive the approval of the committee which he had the honour to represent.

Mr. R. A. HADFIELD congratulated Mr. Riley upon the value of his paper. He said that Faraday and Stoddart had made experiments by melting nail iron with 1, 3, 5, 10, 20, and 50 per cent. of nickel. He could not find many particulars as to the results of their tests, which, of course, were made very many years back. It was mentioned, however, that the metals were very well alloyed together, and that the 3 per cent. material, or nickel steel, was very malleable, and could be worked and hammered like pure iron, thus confirming Mr. Riley's statement. The specific gravity of the metal was stated to be 7·75 in its cast state. The 10 per cent. material was not so malleable, and was more disposed to crack when being forged. Oxidation was not prevented; in fact, it was rather accelerated. The French chemist Berthier made many experiments in the direction of these alloys, but he apparently did not pursue them, or consider them to be of commercial value. Dr. Percy also mentioned experiments of alloys with nickel and

iron, and he intimated that they were strongly attracted by the magnet. Mr. Riley did not mention that.

Mr. RILEY said he had not tried that.

Mr. J. F. HALL said that, from some experiments he had tried, the metal was about the most powerfully attracted by the magnet of anything he had ever seen or heard of.

Mr. HADFIELD said that confirmed Dr. Percy's remarks. Fairbairn had also recorded, before the Manchester Philosophical Society, in March 1858, experiments to determine the strength of alloys of nickel and iron similar in composition to meteoric iron, and also as to its effect upon cast iron. Some of the experiments made in Manchester were carried out with No. 3 Blaenavon pig, and the effect was stated to considerably diminish the strength of the material, both in deflection and impact properties. Fairbairn mentioned that these alloys were susceptible of a very high polish. Mr. Hadfield considered that the paper was another proof of how little was known of the effect of adding other elements besides carbon to iron. Carbon was an old friend, about which they had known the most, because it had given such satisfactory results in the past. It was the increased demands of engineers, and their more severe specifications, that led to such experiments as these. He was sorry to notice that the material did not appear so suitable for castings, judging from the tests quoted. They seemed to give very little elongation in their cast condition. Another thing to be mentioned was the expense. Two shillings a pound for nickel would be rather a serious increase in the cost if it was necessary to add any large amount. He would like to know, if possible, whether this steel hardened when dipped into water. He noticed that Mr. Riley had made tools of it, that it seemed to be of a somewhat self-hardening nature, and that it could be hardened by hammering and cooling in air. Such steels were not usually benefited by water-dipping. He was, therefore, not sure whether dipping in water would harden it, as it did carbon steel. He should like, also, to know something of its electrical qualities in reference

to its conductivity and resistance. He noticed that tests Nos. 10 and 11 were rather of a peculiar nature—the elastic limit dropped from 38 tons in its unannealed state down to 12 tons. He knew that that referred to a higher percentage, but that seemed a very large drop indeed. As regards Mr. Hall's remarks, it was only just to mention that that gentleman had referred to nickel steel, although he did not say at the time that it was nickel, some eighteen months ago, before the Institution of Civil Engineers, when his (Mr. Hadfield's) paper on manganese steel was read. Mr. Alexander Parkes, of Birmingham, in 1870, seemed to have made a considerable number of experiments in the direction of nickel steel, as he took out several patents for alloying nickel with iron—up to as high as 10 per cent. He did not know whether any members present knew the gentleman in question, or what he had accomplished, but it would be interesting to know what was the result of Mr. Parkes's experiments.

Mr. E. H. CARBUTT said he only rose to emphasise a remark made by Mr White, that if Mr. Riley was able to cast armour-plates to the shape required, even although they cost a pretty good sum, it might serve the shipbuilder's purpose to put them in. Those who had followed armour-plate-making knew the difficulty of getting a plate to the shape at all. After the plate was made, a good deal of expense was undertaken in the way of bending it to shape, and then some of the plates were put on an armour-plate planing-machine, where they remained for weeks or months getting planed and cut down, and in the end they had only about one-half or one-third the amount of armour-plate left that they had when they began. If that plan of casting them to shape to fit into position could be carried out with anything like the result shown in the paper, he thought Mr. Riley's material would have a great future before it.

M. GÉNY, speaking on behalf of the inventor, said that experiments had been made in the direction indicated in 1882 or 1883 in Paris. A question had been asked as to what was the property of nickel added to cast iron. When nickel was put into cast iron it increased the strength of the metal.

The PRESIDENT asked if it also increased its soundness.

M. GÉNY said it increased its soundness chiefly. It increased its fluidity, and also its resistance. Armour-plates 6 inches in thickness had been cast in nickel alloys.

Sir BERNHARD SAMUELSON, Bart., M.P., said he thought M. Gény was under a misapprehension as to an objection having been made to the resistance of plates having an alloy of nickel on the ground of corrosion. He said they ought not to be compared with plates that were nickelised; but Sir Bernhard Samuelson thought he was mistaken in thinking that any objection of that kind had been made.

The PRESIDENT proposed that the best thanks of the meeting be given to Mr. Riley for his most able and interesting paper. He thought they must admit that Mr. Hall had very properly, and at the same time very modestly, put in his claim for having given long consideration to the subject. As to the merits of priority of the invention, that was not, of course, the arena for deciding such questions. He did not think that the matter of cost in the introduction of a metal which promised so much was one that was likely seriously to impede its introduction for special purposes, because when they considered, for instance, that for special purposes, like locomotive tires, when steel tires were first extensively introduced into this country by Krupp, they were sold in the market at the price of £120 a ton, yet they made their way against Lowmoor tires of less than one-third the amount. As they had already heard that morning, Bessemer steel rails made their way at £20 a ton because of the superior advantages which they brought; and so, also, a metal like that which, as they had heard, would give a tensile strain of 50 tons, with an elongation of 50 per cent., was likely, and indeed sure, to make its way if the claims which Mr. Riley had made for it were substantiated by experience. He did not think that the question of riveting that material was likely to be a difficulty, if the assertions of their American electric-welding friends were borne out by experience. Professor Thompson had been good enough to send in from the United States a small

sample which he held in his hand, which consisted of copper, brass, German silver, and iron—four metals, all welded into one piece by electricity. They would have their boiler-plates with their rivets placed *in situ*, welded up into a solid mass by electricity, before they were very many years older. He was sure the members would agree with him that they should accord to Mr. Riley their hearty thanks for introducing the subject. That certainly was not the last they were destined to hear of it.

The vote of thanks was then put, and carried by acclamation.

Mr. JAMES RILEY, in reply, said he felt a very considerable amount of sympathy with Mr. Hall that day, and for the last day or two, since he had communicated to him the fact that his investigations into the alloy had been of such an extensive and long-continued character. He could have wished that there had been no possibility of any conflict with himself in any form whatever, and that such enterprise as he had manifested, and his foresight in working out the alloy, should meet with the recompense which the members wished every one to get for his labour, of whatever kind. Having said that, he did not know that he was called upon to make any further remark with regard to the claim which, as the President said, he had put so modestly before the meeting. That was, however, not a matter which affected him in the business of bringing the subject before the Institute. His principal interest lay in the advancing of an alloy which he believed was destined to play a not unimportant part in the metallurgy of the future. What he was concerned with at the moment was, that everything that Mr. Hall had said had confirmed to the uttermost what he (Mr. Riley) had rather understated than overstated in the paper which he had been permitted to read. The question which Mr. Edward Riley had submitted to him was one which he hoped that gentleman would excuse him from entering upon at that stage. He (Mr. James Riley) might mention that Mons. Marbeau in his patents claimed the use of crude nickel. The casting which the members saw on the table was from crude nickel unpurified, exactly as it was brought from the mines in New Caledonia. How far the position which Mons. Marbeau contended for could be maintained

he was not able to state. He was, however, bound to remark, that in the use of what was called purified nickel, they found in one sample which had come to them, in the experiments which they had carried out, an important quantity of the oxide of nickel. That was seriously detrimental to the results which they obtained. Of course, that could be corrected in the operations, if they knew that it was present, just as corrections were made of the oxide of iron which he believed occurred very largely as the result of operations of the basic process. Perhaps he might have been thought to be not as absolutely courteous as was desirable in responding to the question which was asked by Mr. Jenkins; but really, he was bound to say that the question of the cost of production had not been gone into as carefully by him, at that stage, as had the question of the qualities of the product. He had a vague notion, arrived at by some very casual calculations, that the cost of production would not be prohibitive; otherwise he doubted whether the little time which he had found at his disposal in his various engagements would have been taken up by examining so closely into the matter as he had hitherto done. He believed that it would be made a commercially profitable product. Further than that, perhaps, it was not necessary that he should go. He might, however, say that, if he could be favoured with a contract of the magnitude of the first contract which was given to him by the Admiralty for the mild steel used in the building of the *Iris* and *Mercury* in 1875, and at the same price, he would be very pleased to undertake it. Mr. White had spoken as they might expect he would speak on a subject like that. It was scarcely to be expected that he would commit himself either to unqualified approbation or to very sanguine expectations of the results to be obtained from those alloys. Mr. White had said as much, however, as he (Mr. Riley) could have reasonably expected from him—more than, perhaps, had been said in the earlier stages of some other productions which had had to be submitted to the high officials of the public departments. The question raised, as to whether the rivets could be made of strength adequate to that of the material itself, was undoubtedly an important one; and independently of the very wonderful results which were promised to them—should he say by the President, or

by the gentlemen who had communicated with him?—he thought that in the ordinary course of construction they would find that the materials which they were able to give for riveting purposes would be adequate to the other portions of the structure. Mr. White had said that the reduction of scantling was not necessarily a point which they considered much about. He (Mr. Riley) thought he had stated in the paper that there was the alternative choice of having a very much superior and stronger structure if advantage was taken of the additional strength which was given in the material. They knew that even in the mercantile marine some of the highest class lines preferred rather to utilise the superior strength of their ships than to take advantage of it by reduction of scantling. Mr. White could probably, with advantage to the public service, decide to do the same. The character of non-corrodibility, which he believed bulked exceedingly largely in the minds of those who were connected in any way with the mercantile marine, and he thought also in the public mind with regard to the Royal Navy, might apparently be valued too highly, judging from the remarks of Mr. White. He thought he could assure Mr. White that he would not be asked to pay too much for that which Mr. Martell and a great many of them thought an almost invaluable quality. That remark would also apply to the statement that the public services did not always buy the best that was available, but that they bought the best they could get, having due consideration to a commercially profitable result. One could fully appreciate the semi-kind remarks which were made by Mr. White with regard to armour-plates. There was a certain small modicum of encouragement in them for one to proceed further in efforts to produce on a large scale something equal to that which had been produced on a small scale, and perhaps with better results. Sir Bernhard Samuelson had asked a question which he regretted he could not answer. Whether the answer given by Mons. Gény was sufficient he did not know, but he could not confirm it from any knowledge or experience of his own, because he had not made any experiments with nickel alloyed with cast iron. Mr. Martell had been good enough to speak in the kindly manner in which he always welcomed any new introduction. In their friends Mr. Martell and Mr. Parker

they had illustrations or representatives of what he considered should be the public spirit of those who were placed in high positions in public departments. Those gentlemen were always prepared to welcome any one who would introduce anything to them which would apparently further the interests of their clients, or of the public generally, who looked to them for guidance in all those and cognate affairs. The importance of the elastic limit had been dwelt upon by Mr. Martell. The one principal drawback which had always been urged against mild steel (so far as related to strength) was its want of rigidity. That had been spoken of under the convertible term of "elastic limit." He hoped that in the new alloy some improvements in that respect would be found. It was a most important quality, as they all knew. Then there was a very candid statement which had been made by Mr. Martell with regard to corrosion. No doubt there had been a vague feeling of uneasiness in the country, in shipowning and shipbuilding circles, with regard to that matter. They knew that now and again, in some of the engineering papers, statements had been made with regard to the dreadful amount of corrosion which had taken place in some steel ships. Whenever those statements had occurred the public gaze had been focussed upon that failure —had been withdrawn from the 99 per cent. where that corrosion had not occurred, and had been concentrated upon the 1 per cent. where it had been present; and the explanation had never been given, as Mr. Martell had hinted at rather strongly, that it would be well to inquire into all the antecedents of corrosion, who were the people in charge, and how they had discharged the duties which they ought to have carried out. In the 99 per cent. the material had been the same as in that of the 1 per cent., and the corrosion had not taken place; there had been due care of the structure which had been placed in the charge of the people, and it had been properly preserved. Still, that vague feeling existed. He was glad that at last it had been fairly expressed by Mr. Martell in the way that he had done. Corrosion did occur occasionally. Two or three times it had been brought to his knowledge. There were people whose interest it served to pass it rapidly along, and undoubtedly it had had undue weight in the public mind. If, however, proper care were taken, excessive

corrosion would not occur; but, on the other hand, if they could prevent its occurrence, even in careless hands, by some quality that they could give to the steel, then by so much were they doing a very great service indeed, and, as Mr. Martell had said, one which would be appreciated throughout all the shipbuilding circles in the country. He hoped that they might be able to do that, and he was very sanguine that such would be the case. With regard to the question that Mr. Gilchrist had raised, he might state that it was quite correct, so far as his experience at present went, that without the aid of manganese, in due proportions (which he did not feel called upon to state exactly, and, in fact, would rather not state), the conditions of treatment would not be successful. He had pointed out, what was perfectly understood by those who were engaged in the manufacture of steel, that they could make bad steel—an ingot which would not forge. They knew the reason; they were not novices, and it was not necessary to explain further. The same thing obtained exactly in the production of an ingot of nickel alloy. As to the question of the alloy, nickel could no doubt be alloyed with the very low carbon steel, to which Mr. Gilchrist had referred. He knew of nothing to prevent its being alloyed with all the varied strengths of carbon steel with which they were familiar. Mr. Parker had given him due warning of what he hoped was not to be a cycle of tests, and troubles, and worries] which rose up in his imagination as he thought of the experiences through which they had gone in the introduction of mild steel. He should say for himself that life would not be worth living if there was a prospect of again going through the experience that they went through from 1875 onwards with regard to mild steel. He hoped that Mr. Parker's warning did not mean that they were to expect anything of that kind, but that they would be dealt with in that kindliness of spirit which had of late been manifested, not only by Mr. Parker's department, but by the other public departments of the country. He could not answer all the questions which Mr. Hadfield had asked. The question about the magnetic qualities of the alloys had been answered by Mr. Hall. He could himself say that its conductivity was extremely poor and low, the resistance being extremely high; and therefore, although it was not useful in one direction for

electric purposes, it would be found of very great value in the other. The point that he had made of the change in the elastic limit by the annealing of the 25 per cent. alloy was one upon which he had particularly dwelt in his paper. He considered it one of the most important properties that that percentage possessed; it enabled one to use the metal for almost innumerable purposes. He thought that he had now answered all the points that had been raised, and he had only to add that he thanked the members for the kind way in which they had listened to his paper, and to the remarks which he had made.

The following paper was then read:—

THE MANUFACTURE OF BASIC OPEN-HEARTH STEEL.

By J. H. DARBY, Brymbo.

THE manufacture of steel by the basic open-hearth furnace has been the subject of several papers read at the meetings of the Iron and Steel Institute, in which the chemistry of the subject, the shape and the size of the furnace, &c., have been discussed at some length. I propose, in the present instance, to record my own experience of the process, gathered during the past five years at the works of the Brymbo Steel Company.

Coke made from North Wales fuel is not suitable for the manufacture of hematite pig for acid steel-making, as the phosphorus in the pig due to the coke alone is over ·1 per cent. In other respects the coke is of fair quality; the sulphur is under 1 per cent., the ash under 6 per cent.; and when well burnt it is hard enough to work freely in the blast furnace.

As making a suitable hematite pig for acid steel-making was out of the question, it was decided by the late Mr. Robertson and myself, in the summer of 1883, to put down an experimental basic open-hearth furnace, in order to ascertain if the results that had up to then been obtained only on the Continent, where the process was first worked as a "scrap and pig" process, were obtainable, if modified to suit the "pig and ore" process required in this country, where only a limited supply of scrap is available.

It was not at first intended to treat pig iron containing more than ·5 per cent. of phosphorus, but in the experimental furnace I found I was able to eliminate much more, which opened the way for the manufacture of a special pig iron for the process.

The blast furnaces available were of small capacity, 54 feet high by 16 feet diameter in the boshes, and fitted with iron pipe stoves. I found that to produce a pig iron of the following composition:—

	Per cent.
Carbon (combined)	3·20
Phosphorus	3·00
Sulphur	·04
Silicon	·40
Manganese	1·75

it was necessary to burden the furnace with a suitable mixture of ores and limestone, so that a pig iron was produced which was white in fracture, but made with a grey slag.

The furnaces yield 250 to 300 tons per week each, of a regular quality; the iron is very fluid, and is produced by a consumption of 22½ cwts. of coke per ton of pig. The yield of the ores used is 45 per cent.

I find that working hematite ores in the blast furnace, burdened to produce a similar class of pig iron of the following analysis—

	Per cent.
Carbon (combined)	3·80
Phosphorus	·12
Sulphur	·028
Silicon	·52
Manganese	2·05

gives very good results; the metal is fluid, without the usual percentage of silicon, and the furnace works regularly. The pig is white in fracture. Would not this be a suitable pig to use in acid open-hearth furnaces, as it can certainly be made cheaper than rich grey pig iron—of course assuming that the percentage of phosphorus was reduced by using a pure coke?

The experimental steel furnace mentioned was of 5 tons capacity, and above the regenerator chamber, of the "Batho type," there were no end blocks; gas and air being conveyed from the chambers in wrought iron pipes, lined with brickwork. The air was admitted at right angles to the gas-ports, and above them, so as to bring the flame well on to the metal.

This furnace gave considerable trouble. I was unable to obtain sufficient heat; the refractory material in the gas and air tubes often required repairs; and I was glad to abandon the furnace after I had proved that our own phosphoric pig could be manufactured into good soft steel by treatment on a dolomite hearth.

The next work was that of designing and then building four 12-ton, and afterwards two 20-ton furnaces. They were arranged in a line, the charging platform on one side being a sufficient distance above the floor of the works to admit the casting ladle and carriage, which run on rails over a pit parallel to the furnaces.

Each furnace is provided with a separate chimney, ordinary butterfly reversing valves of ample size, and regenerator chambers of large capacity, but similar in shape and construction to most modern open-hearth furnaces.

The furnace proper is composed of two wrought iron sides, supported by H iron buck-staves, well braced together at the top and bottom. The ends are left open; holes are cut in the plates for the three doors on the front side of the furnace, and another hole is made at the back for the tap-hole plates. The plates are also cut away to allow air to circulate for cooling purposes under the furnace bottom and bridge-plates.

The bottom of the furnace is built up of cast iron plates, supported on H iron girders, so as to form a rough outline of the furnace bottom when lined and ready for work. The girders rest on angle iron attached to the side plates. Any movement or subsidence in the chambers must therefore affect the hearth as a whole. This prevents cracking of the material of which the hearth is composed. The silica blocks at each end of the furnace are built in the usual manner, but the roof and side walls are built after the hearth has been rammed in. The former is placed some way above the metal, so as to avoid splashings of the basic slag. The roof is level from block to block; the ends, however, are well inclined, to bring the flame down on the metal.

On the iron plates for holding the dolomite hearth fire-bricks are placed, so that no part of the basic hearth, when finished, is more than fifteen inches thick. As soon as all the brickwork is dry, hard burnt dolomite, well ground and mixed with as little anhydrous tar as will make it stick together when compressed, is rammed with hot irons until the desired shape of the hearth is built up. The taphole is made by a round piece of wood, which is left in and burnt out as the furnace heats up.

The shrunk dolomite or basic material is brought up to the bottom of the doors, and to an equal height all round. On it a layer of about two inches of chrome ore, also ground fine and mixed with tar, is rammed to act as a neutral separator between the acid and the basic portions. Chrome ore is also rammed in between the silica blocks and the basic hearth. The side walls

and jambs are built on the chrome ore. The roof is then put on and the furnace heated up, at first with a coal-fire. There should be no stoppage in putting in a hearth and finishing the roof. A twenty-ton furnace should thus be completed in thirty-six to forty hours. When the furnace is properly dried and heated, the hearth will become very hard. The taphole should be cleaned out, and then filled with dry ground basic material for several inches. This should be well pushed up against a scraper held from the middle door. Anthracite coal is then rammed in, and the outside of the taphole is covered with damp sand.

The charge may now be introduced.

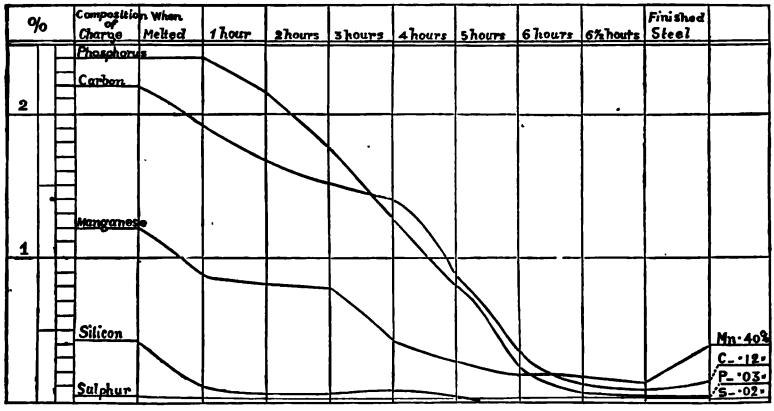
I use 80 per cent. pig and 20 per cent. scrap. The pig I have described. The scrap is composed of either steel or wrought iron. The percentage of phosphorus in wrought iron is not injurious. Limestone is usually charged in sufficient quantity to make a basic slag from the first; scrap and pig follow. When melted and sufficiently hot, additions of iron ore and limestone are made at intervals during about five hours. The first sample is taken, and, from its appearance and fracture, it is judged if sufficient ore has been added. If so, as much as possible of the unspent oxide is reduced in the slag by reacting on the remaining impurities, lime additions being made from time to time. The hammered sample rapidly improves. The edges, which were rough at first, become smooth and free from cracks, the surface of the sample is clean, and when the charge is ready, it will bend over into four thicknesses without any indication of cracking.

Ferro-manganese is then added, part in the furnace and part in the ladle, and the charge is teamed. It runs quietly and solidly, as shown by the fact that the total loss in the mill, including furnacing, crops, and cobbles, is only 8 per cent. on the weight of the ingots produced—that is, in rolling billets, bars, and slabs.

Any kind of iron ore may be used in the steel furnaces, providing it contains a low percentage of silica. Phosphoric acid in the ore does not matter; the phosphorus is already oxydised, and is taken up by the lime. Phosphorus can be as easily eliminated from pig iron with pottery-mine as with hematite ore.

The diagram which I have had prepared was worked with 3·1 cwts. of pottery-mine, and what was equal to 4·2 cwts. of good rough carboniferous limestone per ton of ingots.

Basic Open-Hearth Charge.



The twenty-ton furnaces make from 180 to 200 tons of ingots per week, or 23·3 cwts. per hour, exclusive of Sundays.

The yield of ingots from the weight of pig, scrap iron, and ferro-manganese used, inclusive of iron reduced from the ore, is 93·5 per cent.

The consumption of fuel, inclusive of Sundays and heating-up furnaces that have been off, is 11·07 cwts. per ton of ingots.

Repairs to the hearth are made with ground dry basic material alone after each charge, if the furnace requires it, as is generally the case to some extent round the slag line. The repairs are quickly effected, and the furnace is at once ready to charge.

In the basic Bessemer process, I understand that as much as 30 lbs. of 80 per cent. ferro-manganese is used per ton of steel. In the basic open-hearth, 10 to 12 lbs. per ton is all that is required to give an equal percentage of manganese in the final steel. This seems to me to indicate a striking difference in the composition of the purified material from the two processes.

After experience in the manufacture of over 60,000 tons of basic open-hearth steel, I can say I have never seen "red short" material in our usual soft quality, although I have kept a strict look-out for it. If care is taken to keep the sulphur low—say,

to 0·02 per cent., which is about our average—and if at the same time the excess of oxide is well worked out of the steel prior to tapping, the metal will work and weld freely with a very small addition of manganese.

I have obtained 3660 tons of dead soft steel from one furnace without relining, and it is still at work. The hearth has never been out of order since the furnace was started last December.

Molten pig iron direct from the blast furnace was at one time poured on to the heated scrap in the open-hearth furnace; but although the hearth was well protected with limestone, spread over the bottom, it was most rapidly destroyed, notwithstanding it had been in good condition previously. This method of charging was therefore abandoned. I may, however, say that the duration of the charge was shortened, and if the bottoms could be made to stand, it would be a considerable advantage.

I retain all the slag until the end of the charge, and as this is 25 to 30 per cent. of the weight of the metal produced, it will be readily understood that a furnace for the basic open-hearth process must be considerably larger than a furnace with an equal tonnage capacity working the acid process. Running slag off during the working of a charge means the wasting of oxide of iron. Slag from the basic open-hearth usually contains 13 to 14 per cent. of phosphoric acid, and has fewer shots of steel than basic Bessemer slag.

An average analysis of our soft steel is as follows:—

	Per cent.
Carbon	·12
Phosphorus	·03
Sulphur	·018
Silicon	nil
Manganese	·400

This steel gives about 24·5 tons tensile strain per sq. in., and 15 tons elastic limit, with an elongation of 31 to 33 per cent. in 8 inches.

I would say, in conclusion, that I attach great importance, if uniform results are required, to the composition of the pig iron. A suitable pig is as necessary in the basic as in the acid process of steel-making, but it offers no more difficulty in manufacture.

DISCUSSION.

Mr. BENJAMIN MARTELL (Lloyd's) said he should like to make a few remarks on the paper, as he should not be able to be present on Thursday. This was really a most important subject. They all knew what difficulties they had had with the production of basic steel in this country. The production of that material by the Bessemer process from the highly charged phosphoric ore of the Cleveland district (Mr. Gilchrist would correct him if he was wrong, for he knew a good deal more about it than himself) led to the production of a material that was most unreliable in character. It had been said before—but still, in discussing the question, he must repeat it—that it produced, he was sorry to say, a very bad effect indeed on the minds of all concerned with reference to mild steel generally. Shipowners were prejudiced against it. It turned out most unreliable in character, and naturally, as far as the committee of Lloyd's Register were concerned, that unreliability had created a great scare, and they had objected to accept any material manufactured by the basic process, until a firm in Scotland—the Glasgow Iron and Steel Company—requested them to investigate the manner in which they could produce basic steel for shipbuilding purposes. They did so. They sent two surveyors down to Glasgow, who were there for a very considerable time. He and his colleague, Mr. Parker, went down afterwards, and investigated the manner of their manufacture and their works altogether; and they found that, by the careful process which they adopted, by their method of selection of pig iron, and the intermediary process that they pursued, they were capable of producing steel plates up to half an inch in thickness, of a reliable character, and, as far as they could ascertain, equal to those produced by the ordinary Siemens-Martin acid process. Of course, from their past experience, they were somewhat prejudiced against the use of basic steel on its first introduction; but notwithstanding that, they became convinced, after the crucial tests carried out, that steel could be produced by the basic process, if only proper means were adopted in the selection of the ingredients used in its production, and if those engaged had a proper knowledge of the process em-

ployed. Under those circumstances he recommended, and their committee adopted his recommendation, that they should allow steel produced by the basic process by the firm named to be used for vessels classed in the Register-Book of Lloyd's Registry for plates up to half an inch in thickness. That had now gone on for some considerable time. He did not know that there was a great deal of steel supplied by that process, because shipowners and shipbuilders preferred the ordinary Siemens-Martin steel made by the acid process. But very recently they had had a very large number of inquiries, and this was what he particularly wished to bring before the meeting, because they might not know so well as he did matters of that kind, which came officially under his knowledge. They had recently been requested to sanction the use of steel manufactured by large firms in Belgium and in Germany who produced steel by the open-hearth basic process. They were obliged to continue that very reprehensible system—that most tyrannical system that Mr. Riley had referred to—of requiring exhaustive tests to be made of this new description of steel before they would sanction its adoption for vessels intended for classification. He must say, in passing, with reference to Mr. Riley's remarks, that he thought, instead of reproaching them for having insisted on such careful testing, the steel manufacturers of this country ought to be exceedingly obliged to Lloyd's Register Society for having been so exceedingly careful; that, instead of admitting what steel manufacturers were pleased to tell them was all right, they had determined on going carefully and exhaustively into tests, and had also insisted on these tests being fully complied with. He saw gentlemen present who were steel manufacturers, whom he was very proud to see, and who, he was sure, would endorse the action taken by Lloyd's Register Society. They had had requests from Germany, from large manufacturers; and as their Society was a classification Society for British and foreign shipping, they felt that, in order to avoid any feeling of unfairness on the part of foreign manufacturers, they were compelled to send surveyors over to see whether they could by that process produce such satisfactory steel as Lloyd's committee could accept. The surveyors had now been over there for months, and they had had reports, he, should think, from eight or ten firms in Belgium and in Germany,

where they had been producing basic steel by the open-hearth process. Their officers had conducted most exhaustive tests, and their reports with reference to the steel produced were of the most satisfactory character. The Continental manufacturers were capable of producing by the basic process steel of the most reliable and uniform character, and of which the reports spoke most highly. It was not merely one or two tests that had been applied, but, as he had said before, the tests were exhaustive, extending over a large number of charges. A great number of tests were made of each charge, and the reports were of the most satisfactory character—so much so, that the committee of his Society felt that they were bound to accept the steel manufactured by those firms, subject, of course, to the statutory tests laid down for the steel manufacturers in this country, to be complied with in a satisfactory manner all round. He thought it was perhaps necessary that he should make that explanation, because he could not help feeling that perhaps, if that were not known, it might be said, when some of the foreign steel was introduced into this country, "Well, it is a very extraordinary thing that Lloyd's Register Society have refused to accept basic steel manufactured by English manufacturers, and yet they are willing to accept basic steel manufactured by German manufacturers." Before accepting that steel, they made inquiries to ascertain how the manufacturers produced it, and what ingredients they used. They found, as he said before, that they adopted the open-hearth process, and they selected their pig iron, according to their experience, containing certain qualities—certain chemical elements in each particular pig that they used; and with reference to phosphorus, they accepted in the use of that material no pig iron that contained more than 0·1 per cent. As he had said before with regard to the Glasgow Iron and Steel Company, so in the case of the foreign manufacturers to whom he referred, by a careful selection of pig, and the other elementary materials used, they were capable of producing a reliable and uniform material that they (Lloyd's) were compelled to accept and could not object to. Mr. Hall had used a rough kind of expression, but he was sure that he would excuse him for mentioning it in public, though perhaps he would not care to mention it himself in public. He said, "It is all very well manufacturing

basic steel, but the quality of steel depends upon the qualities of the materials you put in; if you put the devil into the pot, the devil will come out of the pot." That was Mr. Hall's expression; and they found that by using the ore, charged as it had been with a large quantity of phosphorus, it had been extremely difficult, as far as they had been able to determine, to produce a reliable material; but by the selection of a proper pig iron, a material could be produced by that process as reliable as that produced by the Siemens-Martin acid process.

Mr. JEREMIAH HEAD asked Mr. Martell if he would say if, at those foreign steelworks where they were now making such satisfactory plates, Lloyd's were passing them up to any ordinary thickness, or if they adhered to what they did in Scotland, and only passed them up to half an inch thick.

Mr. MARTELL said the reason why in the Glasgow Iron and Steel Works they only passed them up to half an inch was, that they had not machinery adapted to manufacture plates beyond that thickness, and consequently they could not test the quality of thicker plates; but, as they had machinery of larger size in the works he was referring to, they could produce plates to any thickness; and having done so, and proved that they could make them satisfactorily, Lloyd's had accepted plates of any thickness.

Mr. WM. WHITWELL asked Mr. Martell whether the plates tested abroad were from 27 to 32 tons tensile strain, and whether they complied also with all the elements of elasticity required in the ordinary acid plates manufactured in this country.

Mr. MARTELL said those plates were tested in accordance with the requirements of Lloyd's Register Society, such as were required in this country; that was, that they should have a tensile strength ranging from 28 tons up to 32 tons for plates, that they should go through the processes of bending as laid down, and that they should have a ductility of 18 per cent. on a length of 8 inches.

The meeting was at this stage adjourned until the following day.

THURSDAY, MAY 9TH.

The Proceedings of the Institute were resumed this forenoon—Sir JAMES KITSON, Bart. (President), in the chair.

VISIT OF AMERICAN ENGINEERS TO EUROPE.

The PRESIDENT said that, before resuming the discussion on Mr. Darby's paper, he wished to make an announcement in reference to the proposed visit of American engineers to the United Kingdom. As they were all aware, a number of American engineers and American ironmasters were about to visit England and the Paris Exhibition. The Council were hoping as far as they could to assist in offering hospitalities to those gentlemen, and to join with the Institution of Civil Engineers in making their visit to England as agreeable and as profitable as possible. The American visitors would arrive in Liverpool, it was expected, on June 5 or 6. The party would probably be divided into three sections, in order to visit various works and districts in England. The Council had decided that they would appoint a deputation of their number to meet their American friends at Liverpool. In view of their anticipated visit to the United States next year, they desired to make the acquaintance of the American mining engineers and iron manufacturers, and to offer them any hospitality and any assistance that they might require. The Council would prepare an address of welcome, and an offer of services, to be presented, through Mr. Hewitt, to the American mining engineers. The address would be prepared and signed by all the members of the Council, but they thought it would add very materially to the effect and to the influence of that address if it were signed by as many members as possible of the Iron and Steel Institute. They were now preparing that address, but they proposed having a sheet in the room to be attached to it to be signed by all members present who might desire to sign it. He hoped the members would come forward and assist them in that demonstration. They would now resume the discussion on Mr. Darby's paper "On the Manufacture of Basic Open-hearth Steel."

Resumed Discussion on the Basic Open-hearth Process.

Mr. J. W. Wailes said that he was naturally interested in Mr. Darby's paper, because for about the same period he had been pretty actively engaged in the development of the basic open-hearth process. On reading Mr. Darby's paper, one got a feeling that the difficulties had been insignificant; and, in fact, looking back from where they stood now, it seemed as though the difficulties had been small. But he assured them that at the time they began—about five years ago—and looking forward with the information they now had, the difficulties had not been at all small. About the spring of 1882 he commenced making basic steel with a small Bessemer converter, under the direction of Mr. Gilchrist. They met, of course, with the usual difficulties, which were probably augmented in their case in Staffordshire, as the iron they had to operate upon was of a difficult nature to treat. At that time he spoke to Mr. Gilchrist, and strongly urged his opinion that the basic open-hearth process would offer great advantages for treating phosphoric iron. Mr. Gilchrist did not on that occasion make any remark, by way of reply, but he gathered that that gentleman's experience with the open-hearth process had not been unattended with difficulties. He thought Mr. Gilchrist was fresh from his operations at the steelworks of Scotland, where the furnace, pretty much as described now by Mr. Darby, had been used. The trouble attendant on keeping the lining had been found very great. That led Mr. Wailes, step by step, to alter and modify the furnace with a view to the treatment of iron by the basic process. The outcome of that experience was the first form of the Batho furnace, which Mr. Darby had condemned; but as that furnace was designed more than five years ago, and the furnace at that time was very different from the furnace now in use, he had no doubt that Mr. Darby would considerably modify his opinion at the present time. There were two or three points in connection with the lining of the basic furnace on which they seemed to have diverged. Mr. Darby, he believed, commenced, as he had himself done, by lining the whole body of the furnace

with a basic lining, as the Bessemer converter was lined. For himself, he was scared by the difficulties that were shown him by others who had tried the basic open-hearth principle, particularly Mr. Gillott, who had then been working it for some time at Farnley Ironworks. Mr. Gillott told him that the great difficulty he had found was that of keeping the lining above the basic part of the furnace. He had had many linings in one furnace, some of them standing for a very short time indeed. Mr. Gillott stated that he considered it was quite possible, if it was not perfectly certain, that they could produce a very beautiful material, and with considerable certainty, but he doubted it as a commercial enterprise. Of course, with those disheartening things before them, they had to begin with a good deal of caution. For himself, he began with a very small furnace of about 2 tons capacity, and then went up to 8 tons. He perfectly agreed with Mr. Darby that a large furnace was the proper thing to work the basic process in; they thereby got a very much fuller range of heat, and less variations in temperature. The small furnace gave very great trouble, and he thought Mr. Darby had now struck a very correct idea in adopting a 20-ton furnace; that was about his own idea as to the profitable size for working the basic process. Of course, five years ago, when they stood at the threshold of the business, it was not very likely that they were going to risk beginning with a 20-ton furnace, and perhaps making a gigantic failure. A small failure looked more palatable than a large one. About the lining of the furnace, Mr. Darby gave them a pretty clear outline of the way in which he proceeded—that was, he rammed in with shrunk dolomite and tar on the hearth of the furnace. For himself, from his own experience, he found that that was a very expensive operation. They could quite understand what the lining of a 20-ton furnace would be: there was a very large area, and they had to beat this with small irons and ram in the basic material slowly, layer by layer, and the consequence was, that a great deal of time was lost and much labour was employed. He improved upon that very considerably by the introduction of basic bricks. It was very much easier to prepare the basic bricks. They rammed them better, got them into better shape, and put the bottom of the furnace in very rapidly indeed.

But there was still a better plan that he thought Mr. Darby would eventually adopt, and that was, to put in the bottom exactly as they put in an acid furnace bottom—namely, by burning it in, beginning with a thin acid lining, with a little basic material spread over it, and then on that to put in the bottom as in the acid furnace. But to do that they must have a material of such a composition that it would flux and run together. They added a little silica sand, just sufficient to obtain the necessary flux. When that was done the bottom became, to all intents and purposes, as sound and solid as an acid hearth, and there was no more trouble or difficulty in the management afterwards. He thought that all users of the basic process would find that a very much readier and more economical way of putting in the bottom than the laborious one of ramming it in as Mr. Darby described. He might advert for a moment to the Batho furnace. The Batho furnace had received rather strong condemnation by Mr. Darby. It had been described by himself and others on two or three occasions. The principle involved was, that the body of the furnace was separated from the other parts of it; and since Mr. Darby's experience with the furnace, the improvements of Messrs. Riley and Dick had been added. Those were separating the regenerators, making them each single, like hot blast stoves, allowing each to be a separate structure, so that any expansion or contraction took place within itself, and the damage to the furnace and other parts was thereby obviated. It was very essential in a basic furnace that it should be as little disturbed as possible from expansion, or from other mechanical causes; and though Mr. Darby condemned the Batho furnace, he shortly afterwards went on to say: "The bottom of the furnace is built up of cast iron plates, supported on H-iron girders, so as to form a rough outline of the furnace bottom when lined and ready for work. The girders rest on angle iron attached to the side plates. Any movement or subsidence in the chambers must therefore affect the hearth as a whole. This prevents cracking of the material of which the hearth is composed." How could they possibly have from anybody a stronger plea for the principle they had adopted? Here was exactly, in a nutshell, the difficulty that they had sought to overcome. Any subsidence of the lower structure of the furnace

would disturb the melting chamber, cause cracking, and consequently give serious trouble. Mr. Darby, though he condemned the Batho furnace for basic working, immediately pointed out the difficulty which that particular furnace was designed to overcome; and Mr. Wailes left it to any engineer to say whether the plan Mr. Darby described of building the furnace on an everlastingly moving structure of brickwork, that was bound, from its very nature, to be heated and cooled down at rapid intervals, was as good as the plan the designers of the Batho furnace had adopted in separating and creating the movement in each individual part. He thought Mr. Darby had fully admitted that in principle, at any rate, the Batho furnace was perfectly right. Mr. Martell had on the previous day touched upon the question of the quality of basic steel, and he was pleased to hear that his examination of the steel made in Belgium had been very satisfactory. Mr. Martell seemed to be perfectly willing to give a fair trial to the steel that had been submitted to the meeting by Mr. Riley—namely, the nickel compound; and he thought it was only for basic open-hearth steel-makers to undergo the same amount of torture that Mr. Riley had mentioned, and which he himself had a very lively recollection of as attending the introduction of mild steel from the acid furnace, and the position of open-hearth basic metal would soon be a secure and very important one.

Mr. STODDART (Parkgate) said that he had not been aware until the President had invited him, that he would be expected to speak upon the subject. He might, however, say that at the Parkgate Ironworks they had recently spent a large sum of money, some £80,000, in the erection of a new steelworks for the purpose of making steel bars and plates by both the open-hearth acid process and by the basic process. In putting down the works for the basic process they went very much upon the lines which Mr. Darby had mentioned in his paper. Some twelve or eighteen months ago, he had occasion to supply certain kinds of steel, and they bought a large number of slabs from the Brymbo Company (which was represented by Mr. Darby). Those slabs gave such excellent results that the directors of his company decided to put

down the basic open-hearth. They did not adopt the Batho furnace, or any other description except the ordinary Siemens furnace with very large ports and checker chambers. They had found the results to be quite satisfactory. They had some little difficulty in starting the basic furnace, but that was probably inseparable from the introduction of a new manufacture, and where they had to get workmen from all parts of the country, many of whom were previously unacquainted with the process. But he thought that all their troubles would only have resulted in a loss of something like £1500 or £2000. He was glad to say that they were working continuously with open-hearth steel, and they could make it to almost anything from ·07 up to ·13 carbon. With regard to the quality of the material, he could bear out to the fullest extent all that had been said by Mr. Wailes and Mr. Darby. He thought that in the basic steel they had a metal which would give them everything they had been accustomed to obtain from the best Yorkshire iron, at something like about a third of the price. With regard to what Mr. Martell said as to having gone to some trouble in making experiments at the Glasgow ironworks, Mr. Stoddart had invited that gentleman to come down to Parkgate, when the works there were completed, in order that he might make a series of tests, starting with the ironstone and ending with the finished plates. They would have a plate mill, when finished, with a 36-inch train and 12-feet rolls, and he hoped they would be able to roll plates up to 11 feet 6 inches diameter, and of, perhaps, 10 feet 6 inches in the square. With regard to the quality of the material, such steel as they had produced stood from 24 to 26 tons tensile strain. They could smith it, and they could weld it, and after having welded it they could bend it in any direction over the weld, and in fact they could do almost anything with it. The steel rolled kindly, and they had not the same difficulty with it that they had with what he might term "treble best iron." Every gentleman who had been accustomed to work with high brands of pig iron knew that it blistered, and that they got rather a larger percentage of waster plates than with the common iron. He felt sure, from the little they had as yet done at Parkgate, that the open-hearth basic steel would be the metal of the future, if the authorities at Lloyd's and at the

Admiralty would consent to lower their tensile strain. Instead of commencing at 27 to 32, let the authorities say 24 or 25, and go up to 30 tons. If that was done, he thought that the larger ductility of the material was such that it would be found a very satisfactory material for every purpose for which it was required.

Mr. E. P. MARTIN said that they had had some experience of working on the basic hearth at Dowlais, and with the knowledge obtained from other makers, he could state that in starting an ordinary 7-ton Siemens furnace, they had never had the slightest trouble with the bottom. He believed (at any rate that was their experience at Dowlais) that much more had been made of the bugbear silicon than it deserved. They had found that, by working a very low amount of silicon in the mixture, the hearth rose, and they had occasionally to use a, comparatively speaking, silicious mixture to bring it down to its proper bearings. The greatest trouble they had met with had been in the matter of sulphur. They had made several experiments with the view of trying to remove it by the addition of manganiferous and other ores, but, he was sorry to say, not with the success they wished. As far as the quality of the material was concerned, they found it excellent, and it would stand a great amount of punishment. They had produced some steel made from hæmatite pig iron on a basic hearth, and he ventured to say that a softer and more ductile metal had never been produced. They had been rather disappointed with the experience they had had in the matter of welding. He had hoped that the soft scrap made on the basic bottom would have been soft enough, if piled in the ordinary way, to have rolled into solid bars in the mills. They could easily weld it in an ordinary smithy fire—more easily than the ordinary soft Bessemer or Siemens steel. Still, it did not weld with such facility as to enable it to be mixed with other material and passed as ordinary wrought iron. He would like to ask Mr. Darby what were the iron-producing materials he had used to make his pig iron from.

Mr. G. H. STRICK (Swansea) wished to ask one question which had been partly led up to by Mr. Martin. He saw that the per-

centage of phosphorus in the pig ran up to 3 per cent. That had probably been produced by the use of a certain appreciable quantity of puddle cinder. If that was the case, he presumed that, with so low a percentage of sulphur as 0·04, the slag in the blast-furnace must necessarily be very basic. He would like to know whether any difficulty had been experienced in the working of the furnace owing to the very basic character of the slag, which he presumed must exist in order to get so low a percentage of sulphur; and also whether 22½ cwt. of coke per ton represented the average consumption of fuel over a period of about six months? Mr. Darby and Mr. Wailes had both mentioned that the quality of the iron had been very regular, and Mr. Martin had confirmed that to a certain extent. As a manufacturer of tin plates, for which they required a very soft, and at the same time a very uniform, material, he would like to know whether the quality was as regular as that now produced by the acid process. He thought he might say—and Mr. Martin could confirm it—that even in the ordinary Bessemer process, as now conducted in South Wales, the quality was extremely uniform. Did that uniformity exist in the basic process?

Mr. P. C. GILCHRIST said he thought that Mr. Darby was to be congratulated upon his very able paper. It was one of the most satisfactory papers that the Institute had ever received, as it showed that the difficulties which did exist at one time had been thoroughly overcome, and it told, not what he wished to do, but of the ease with which he was now actually making some 500 tons per week. On the Continent they had gone into the subject earlier than in England; but it must not be forgotten that in this country the overcoming of all the difficulties in carrying out the pig and ore process (which was alone applicable to England) had been due very largely indeed to the unceasing energy of both Mr. Wailes and Mr. Darby. It was very interesting from a scientific point of view to see that what one would expect to happen really had happened,—namely, that as the conditions were oxidising, the phosphoric acid that existed in iron ore was not reduced in the bath, and that therefore one was able to use for ore any of the phosphoric ores, such as pottery mine, provided that it was low in silica. He

always hoped that that would be so, and he was glad to find such an important fact so clearly recorded. One of the most satisfactory features in the basic Siemens process was the fact that under certain conditions it was possible to make steel without the addition of any spiegel or ferro, as the charge could be worked (if a suitable pig were used) so as not to produce burnt iron which had to be restored by manganiferous additions. In both the acid processes, and generally in the basic Bessemer process, one was obliged to make burnt iron first, and then restore it by the addition of ferro or spiegel. Mr. Darby recorded that if they used a pig iron low in sulphur, and containing 1 per cent. of manganese and a tenth of phosphorus, the charge worked perfectly well as tapped from the furnace, without any addition of ferro or spiegel. Where the material was to be used for smithing purposes, that was undoubtedly a very important factor. He thought that it was a very encouraging feature also because, with further experience, they would be able to obtain the same result when using phosphoric pig. That brought him to one other point—namely, the difficulty the basic steel manufacturers always had had in the past in getting high strains. It had been much easier for them to get the low strains, and they naturally wanted to persuade people that the low strains were best; but other people said, "We can make a hard and cannot make a soft steel; we think that the hard is the best." So it had been, and the other manufacturers had had the best of it so far. He thought that through the discovery made by Mr. Darby that difficulty had been overcome. Mr. Darby had not read a paper on the subject, but he had taken out a patent, open for everybody to see, in which was described a method by which carbon could be put into steel. Briefly, it amounted to this, that by filtering steel through charcoal they could get the carbon as high as they liked up to 1 per cent. The amount of carbon they got in depended upon the weight of charcoal used, so that if one wished for either ·15 or 1 per cent. carbon one could have it, and this without the addition of any ferro or spiegel. In that way he considered that it was open to anybody now to give buyers basic steel with a tensile strength of 28 to 32 tons, or even higher. On the Continent, Lloyd's tests were very successfully obtained by adding in the ladle, before the slag came, molten carburising

material, such as a spiegel low in manganese. In the paper mention was made of the non-success of using metal direct from the blast furnace. At Witkowitz, when he last heard from them, they were using metal direct from the blast furnace in a basic Batho furnace, without unduly "punishing" the bottom. The increase of speed in working was nearly 50 per cent. If this practice could be introduced into this country it would be an undoubted advance. He thought, however, they might claim credit already for working a little more quickly than was usual, for in a 12-ton furnace, when using about 70 per cent. of pig and 30 per cent. of scrap, the average was 15 to 16 charges per week; a rate of working that had not been beaten by any Siemens work in England, whether acid or basic, when using the same proportions of pig to scrap.

Mr. JOHN HEAD said he had not intended to speak upon the paper, as it dealt rather with the quality of steel made than with the construction of the appliances used for producing it. The quality of the product would vary, owing to many circumstances, more or less under control at different works. The information given in the paper concerning the furnace used was meagre, but he noticed that the consumption of coal was returned as exceeding 11 cwt. per ton of steel made, the charges being 20 tons each; he considered that a high figure, the consumption in the open-hearth furnaces, heated by radiation, being only about 8 cwt. per ton of steel made. But Mr. Siemens was not prepared to stop at this result. An improved type of regenerative gas furnace which he had recently caused to be constructed, for heating large iron piles for welding and rolling, had shown that much better results could be obtained. In welding iron in the new furnace the consumption of fuel was found to be reduced to about 3 cwt. of small coal to the ton; which showed a saving of 50 per cent. upon the recorded results in the original type of regenerative gas furnace used for the same purpose, and a saving of fully 75 per cent. as compared with coal-fired grate furnaces. At the autumn meeting, to be held in Paris this year, he promised to bring the new furnace before the members in a formal manner, so that he would not now enter into particulars forestalling the paper he intended to read. That paper would contain the results of practice at several works, in England and on

the Continent, where the new furnaces were being built, and he hoped it would also include the results of an open-hearth steel-melting furnace. He might add that Mr. Siemens had advanced three-fourths of the money required for the construction of the trial furnace referred to, stipulating that it should be returned to him after six months' working, or the furnace should be destroyed; and he was pleased to say that less than three months after the furnace was started the proprietors of the works sent a cheque to refund the advance made, and expressed their great satisfaction with the working of the new furnace.

Mr. F. W. PAUL said the paper opened up a very large field for criticism. The basic open-hearth process was supposed to have been working satisfactorily for some time, but up to the present he thought the theoretical part had been principally dealt with in all papers that had been read. He attributed a great many of the difficulties which had been met in basic open-hearth working principally to the fact that Bessemer basic was started first, and naturally in starting the basic open-hearth they had followed the lines adopted in Bessemer basic working. If they for a moment imagined that the acid Bessemer had been employed, and they had suddenly to start with the acid Siemens on the same lines, they would naturally expect to meet with the same amount of difficulties, especially when they came to the modes of putting in the bottom. Mr. Wailes had suggested a good method of putting in a reliable bottom, because if they were to put in an acid bottom with gannister, rammed after the style of the Bessemer lining or a Bessemer plug, he should look forward to nothing but difficulties throughout. The basic bottom, or the lining of any furnace, he looked upon rather as a vessel in which to conduct the operation, in much the same way that they would use a beaker or a crucible in a laboratory. Mr. Gilchrist had undoubtedly touched upon a very important point in mentioning the manganese in pig iron for basic working. They had heard a great deal about oxidation at the meeting, yet in no paper that he knew of had that point been brought prominently before the Institute. They dealt in generalities and suggestions such as, "We use a suitable selection of pig." What constituted a suitable selection

of pig? Mr. Gilchrist said one with manganese. He quite endorsed that choice for Bessemer working, but he failed to see its utility in open-hearth working. Undoubtedly it was necessary in basic Bessemer work to have much manganese in the pig iron, and the serious part of their troubles, to his mind (he was open to correction), had been met with simply because they had not ensured manganese being there in sufficient quantity to prevent that injurious oxidation which took place during the after-blow. If basic open-hearth working was to be continued, and to supersede acid, care must be exercised to guard against the evils of allowing metal, when it contained little manganese, carbon, or phosphorus, to be in contact with slag rich in oxide of iron at a high temperature. If due attention were paid to this important point, there was no greater risk than in the acid process of the charge of metal becoming injuriously oxidised, irrespective of how little manganese may be present in the initial pig iron. The conditions most favourable for the satisfactory elimination of phosphorus in this process were of such a nature as to be a direct preventive to the metal becoming injuriously oxidised. In the event of a charge being so far decarbonised as to no longer cause any motion, or, in other words, "to be off the boil," and it being desirable to still further eliminate the phosphorus, the bath of metal was recarbonised by the addition of a few hundredweights of pig iron, which caused the bath to boil vigorously, agitating the whole mass, and bringing it in direct contact with slag, which, if sufficiently basic, speedily removed the remaining small quantity of phosphorus; so that, whilst recarbonising indirectly conduced to the elimination of the phosphorus, it at the same time minimised, if it did not entirely prevent, injurious oxidation. The rates of elimination of the elements were entirely different in the Bessemer and open-hearth processes; therefore he thought they should strike out and work in different modes, and while they were working in a basic open-hearth, forget all about the Bessemer system. The carbon must of necessity be first eliminated in the Bessemer, whereas in the open-hearth phosphorus and carbon were eliminated simultaneously. He thought that when the process had been worked out to a greater extent they would be able to make steel of sufficiently high tensile strain to meet all requirements for boiler and

shipbuilding purposes. If the process were conducted properly and the bottom were good, which was an essential part of the elimination of phosphorus, he failed to see why the phosphorus should not be eliminated before all the carbon. It had been asserted that all charges were of uniform composition from basic working. It might be so when all was going well, but even in acid working, unless they attached the greatest importance to the condition of the slag, they were as liable to irregularity in an acid furnace as they were in the basic open-hearth, except that it was more marked in the case of the basic, because then they got phosphorus, and the charge was useless. A short time ago he had occasion to look into the reason of the difficulties to be met with in basic Bessemer steel, and he traced those difficulties to oxidation. Although some samples would give a perfect analysis, and a thoroughly reliable test, yet the nature of the steel was such that, if they merely nicked it, it snapped off suddenly and sharp, the fracture being bright and lustrous, instead of dull or leaden. That he traced undoubtedly to the fact of there not being sufficient manganese in the initial pig iron to guard against oxidation during the after-blow, and in proportion as the manganese was low in the metal while being blown, so was the oxide of iron high in the steel. If they attempted to get rid of that oxide of iron by the addition of ferro-manganese, as Mr. Gilchrist proposed, they were bound to get the phosphorus back in the steel. Mr. Darby suggested a white pig iron for working in acid open-hearth furnaces, and asked the question whether such a pig would not be suitable. He (Mr. Paul) considered it very unsuitable. The manganese that was present would undoubtedly cut the banks very seriously. Besides, there was a very low percentage of silicon. In a grey pig iron, that silicon, on its elimination, was replaced by an equivalent of iron from the ore, whereas in melting a manganiferous pig in an open-hearth furnace the bulk of the manganese was oxidised while melting in the furnace, and therefore did not set free an equivalent of iron from the ore. Such an iron as that was likewise open to the objection of being very readily wasted while melting, more so than melting a grey pig iron rich in graphitic carbon. So that, without entering too closely into the economical aspect, either in production or in using an iron of that sort, he

would point out that the yield of ingots would be considerably lower than when using a grey pig iron, and probably would tell ultimately against the saving of production in the blast furnace. Touching for a moment on the type of furnace that Mr. Darby used at first, he thought that gentleman would corroborate him in saying that every one who started a basic furnace generally made a mistake in having too much oxide of iron present in the slag. In fact, only two years ago, Mr. Harbord recommended it in his paper on basic working, and at that meeting it was not pointed out that that was not the proper mode in which to conduct the basic open-hearth process. Mr. Darby in his paper suggested the very opposite. He said that if the oxidation had been carried far enough, they should add lime, which meant, "Keep your slag as neutral as you can," which was best judged by its consistency, as Mr. Paul had pointed out in a written criticism to the *Journal* on Mr. Harbord's paper. Those additions of lime were not made solely to ensure sufficient basicity to take up the additions of phosphorus which had been eliminated from the pig, but to keep the fluidity of the slag right. There was more dependent upon watching the slag in working in an acid furnace or a basic furnace than merely being guided by samples of the metal. Another condition was that, with a thin slag, containing oxide of iron in excess, it was a matter of impossibility to get heat in the metal. He doubted very much whether, in a puddling furnace lined with ore, it was actually possible to keep iron molten. Of course, it might be open to the objection that the bottom and the fire-bricks would melt before the puddling furnace got sufficient heat; but with that type of slag he said that it seemed a matter of impossibility to get the metal sufficiently fluid to carry on the teaming operations, whether conducted on dolomite, magnesite, or chrome bottoms in a Siemens regenerative furnace. It seemed to him that it would all waste away; and in starting, any one who was doing basic open-hearth working would admit that they were subject more to the difficulties of getting heat in the metal than they were in the acid process, simply from the slag present. In the acid process he had seen a furnace that could not get heat. The furnace was said to be at fault; it was supposed that it wanted checkers; yet when they put the slag right the heat would come on directly. The same thing occurred

in basic working. In the furnace in question, he had no doubt that Mr. Darby, before he had gained the experience he now had, would naturally have an oxidising slag, as small additions of iron ore affected the slag to a far greater extent than was the case in an acid furnace. With a slag of that description, he could well understand Mr. Darby not being able to get heat. He knew that the first experiments he conducted were made in a furnace of a very similar type, and were he inclined to be critical, he might endorse what Mr. Darby had said; but he attributed the difficulties to the want of knowledge in working that process, and likewise to the small capacity of the furnace. In tapping such a small quantity as 3 tons, the chances were that unless the tap-hole was of a good size, and the ladle very hot, part of the charge would set in the ladle. Even with 15-ton acid furnaces it was a daily experience in tapping that the tap-hole was not sufficiently enlarged to allow the steel to run out of the furnace freely till after one or two tons had run out slowly. Mr. Darby had mentioned the repairs to the air and gas ports. He would ask whether Mr. Darby considered that as telling more seriously against that furnace than the difficulties that had been met with in the chambers of ordinary Siemens-type furnaces. He thought that if that matter were looked at, and considered in all its bearings, especially with regard to the lime-dust carried over, a good many gentlemen would bear him out in saying that one might reasonably expect that those difficulties might likewise be mentioned, as well as the ordinary repairs to the gas and air ports, which really were readily accessible, whereas the collapsing of chamber arches meant an exceedingly heavy cost for repairs.

Mr. THIELEN (Ruhrort) said he would make a few remarks as to the working of the acid and open-hearth processes in Germany. He believed that about 70 or 80 per cent. of the metal produced in the Siemens furnace was produced nowadays in a Siemens basic furnace. There were very few Siemens acid furnaces working, and where new furnaces were put up, they were almost invariably erected for the basic process. There had been an enormous increase of material in that way in Germany lately—quite an alarming increase; and those districts which were lying rather out of the way could not compete with the iron produced by the Siemens basic furnace. They made the soft steel for high

qualities, which was at the present moment in great request in the German market, entirely in the Siemens open-hearth. By far the larger percentage of steel used for welding and for machinery purposes was basic steel. A great many experiments were being made as to the size of furnaces, and as to the materials used in their construction, but he did not think a definite decision had been arrived at. In Germany, they used the Siemens open-hearth furnace chiefly with scrap, and so far as his experience went, there was only one firm which was using pig iron alone. There had been some interesting experiments—which were now almost beyond the stage of experiment, as they had been reproduced in several important works—as to preparing the charge in the basic converter by decarburising it, then moving it into a ladle, and then from the ladle into a Siemens basic open-hearth furnace. Of course, they could turn out an enormous quantity of Siemens basic steel by that method, but at the present moment, when there was such a very heavy demand for Bessemer basic steel, it was not so much worth while for the works to do it; but he was quite sure that as soon as the demand fell off to a certain extent, that mode of working would be increased. In Germany they were almost bound to work on the basic principle. They had hardly any ores in Germany (except at a very great distance from the coal) which could be used for the acid Bessemer process, but they had enormous deposits of ore which could be used with the Bessemer basic process with advantage. To import foreign ores, as they had done within the last few years, had become very difficult, because, as the meeting knew, the freight market was very high. The Bilbao ore was decreasing in quantity, and perhaps in quality, and there were only very few works in Germany which imported foreign ores to any very great extent. As long as they could not reach their deposits in Alsace-Lorraine, Luxembourg, and the Rhenish Westphalian provinces, they were bound to import ores of a character suited for the basic Bessemer. They imported French ores containing about half of 1 per cent. or three-quarters of 1 per cent. of phosphorus. They found themselves rather short of basic ore at the present time, but they hoped to get supplies from Alsace-Lorraine, Luxembourg, and the Rhenish Westphalian provinces. They had the Moselle flowing from that

direction into the Rhine. The Moselle could be used for navigation, and they hoped that the Government was going to convert it into a large canal, which would enable them to ship those ores at much lower rates. There was a large deposit of the oolitic iron ores in that direction, and if the scheme was carried out, they might then expect in Germany an enormous increase of basic Bessemer working within the next few years. There were already three works in the Saar and Lorraine district which were about to erect large basic Bessemer plants.

Mr. JAMES RILEY had been hoping that from some source or other they would have heard something more of the matter which Mr. Thielen had just referred to—the use of magnesia. He confessed that, in considering the subject of the lining of a basic furnace, he had hesitated a good deal as to whether he should put in a dolomite bottom in a large new furnace they were just completing, or whether he should use magnesite. The testimony, which had come from several sources, had been very largely in favour of the use of magnesite, and he was hoping that their friend Mr. Thielen, or some other gentleman from the Continent, would know something of the subject, and that they would have contributed it then, having such a capital opportunity. Then there was the other system—what was called a neutral bottom. He was hoping that Sir Lowthian Bell would have told them something of that. These contributions would have been of service to more than himself if they could have got them at that stage. He was told by an American gentleman whom he had met not long ago, that he had found his furnace lined with magnesite work remarkably well; and so strong was his friend's testimony, that it nearly turned the balance in his mind in favour of using that lining for some furnaces they were building. But again, two or three weeks ago, another American gentleman whom he met told him—"Ah! just be careful what you are doing about magnesite. The furnaces you were told about did work remarkably well for a long time, but the magnesia bottom appeared to get into a condition of being saturated with silica"—a curious condition, certainly, but those were his friend's words—"and it was next to impossible to dephosphorise upon these soles." As he had said, some further informa-

tion would be extremely useful to others, like himself, who at that moment were hesitating as to the course they should take in the adoption of that particular dephosphorising process.

Mr. E. WINDSOR RICHARDS said that it might be interesting if he said a few words as to the type of furnace he had used. Some of their members might be contemplating the erection of a basic furnace, and might like to know the experience that he had had. As to the form of the furnace, when they first started making basic steel in the open-hearth it was said that the circular furnace was the best form, and they accordingly erected a round furnace. He was bound to say that it worked very badly indeed. The port was a large one at each end of the furnace; the gas ran away from the one port to the other without properly keeping the tapping-hole hot. Another great trouble was, that the roof lifted very much. In spite of anything they could do in putting in pieces of wood in the joints of the bricks, or placing heavy weights on the top, the dome lifted, and lifted, and lifted, until at last the flame just followed it, and went out from the port at the other side, doing little service. They might imagine the trouble they had had with that furnace. When Mr. Wailes read his paper at Owens' College, Manchester, he gave them a glowing account of an elliptical furnace that he had erected, and which was working admirably. He was determined, as soon as he possibly could, to get out of the round furnace and put up the elliptical furnace. There was a good deal of sound sense in Mr. Wailes's argument, that in narrowing the furnace the flame would fill it better and the difficulties of the tapping-hole would be overcome. In a very short time, in the course of a couple of weeks, he made the round furnace into an elliptical one, and made it exactly of the size recommended by Mr. Wailes. But if he had not heard that paper read by Mr. Wailes, it would have saved a good deal of money and considerable vexation of spirit. Why they had all gone away from the rectangular form of furnace of Sir William Siemens he could not for the life of him imagine. However, they had come back to it, and their troubles had pretty well ceased. The furnace should be a large one, and should hold at least 20 tons of steel. The system carried out by Mr. Batho—no doubt suggested by Mr. Riley—which involved

the separation of the furnace from the regenerators, was a most excellent one. Whereas it took three weeks to clean out the regenerators of an ordinary furnace, by the Batho system the regenerators could all be cleaned out and the furnace be at work in three days. As to the quality of steel by the basic process, they had made a large quantity, and in a very short time they had no difficulty whatever in satisfying Lloyd's requirements. He did not see why Mr. Stoddart should trouble himself about going down to 24 or 25 tons. They could easily get 30 tons; it was simply required to add a little more ferro-manganese, and if they got the carbon up to ·12 they would get 30 tons of tensile strain. As to Mr. Thielen's remark about Alsace-Lorraine ores in the furnace, they in Cleveland used Cleveland ironstone with pig iron and scrap, so that he did not think Mr. Thielen would have difficulty about that. His reason in rising, however, was to reply to Mr. Riley's question about the neutral lining. He had been in St. Petersburg a few months ago, and went over the Alexandroski Steelworks. The manager there was very courteous, and showed him what he was doing. They had used chrome-ore linings for some time past, and he was fortunate enough to see a furnace that had just been completed, and was ready for work. He went inside the furnace, and examined it carefully. The chrome ore was very dear. He asked the manager how much it cost them, and he said £4, 10s. a ton. It required a great number of tons to line a 15-ton furnace. They did not trouble to dress the ore in any way—they just built it as a rubble wall; the whole of the bottom and the sides and ports were all built with chrome ore, the pieces were made to fit in as well as they could, and the mortar used was very small chrome ore mixed with tar. They assured him that the furnace worked admirably, that there was very little difficulty, and that practically the furnace would last indefinitely. Sir Lowthian Bell, he thought, would be able to tell them in the course of a few months his experience at Clarence. He believed, apart from a little trouble which they all experienced in first trying a new thing of that sort, that it would be a very great success.

Mr. JEREMIAH HEAD said he wanted to say a word or two, rather from the consumer's point of view. Some three or four

years ago he had a contract with the Brymbo Steel Company for ingots; those ingots he rolled into plates, and those plates were to a large extent afterwards made into Galloway tubes. The distinguishing quality he found in the plates, and one which had been alluded to by other speakers, was their extreme softness. They could always be relied upon to weld. There was no trouble in that respect, no cracking behind the weld, nor any other difficulty. At the same time he was rolling ingots made by the basic Bessemer process into plates, and on several occasions he tried to make Galloway tubes out of these, but without success. What the reason was he did not know—it might have been since overcome—but he had to desist because he could not get them to weld with certainty. That was not so with Brymbo ingots. He had tried a great many tensile tests. By both processes the plates were very soft, more so than was requisite to fulfil the tests required by Lloyd's. He was glad to hear from Mr. Gilchrist that there was a prospect of getting steel made by the basic Siemens process, of a quality to fulfil Lloyd's and the Board of Trade tests; because he thought that until that was done a large market for them would be closed. He understood, however, from Mr. Martell that in Germany they had already fulfilled Lloyd's requirements; and although he did not say so, he presumed it was without recourse to the new patented process to which Mr. Gilchrist referred. That, therefore, was a matter of very great interest to them all. Some one had said—he thought it was Mr. Martell—that pig iron, to be successfully worked by the basic Siemens process, must be a special pig iron, and that it should not contain more than 1 per cent. of phosphorus. That was rather discouraging to those who were interested in the districts where pig iron containing much more than that was ordinarily produced. He was, therefore, glad to hear from Mr. Richards that morning, that in his experiments he found no great disadvantage from using, if he understood him correctly, Cleveland pig containing the ordinary percentage of phosphorus.

Mr. WINDSOR RICHARDS: Yes.

Mr. HEAD said it was certainly most important that the process should be adapted, as far as possible, to the materials that were

easily produced in this country, and not that they should have to adapt the materials with great difficulty to the process.

Sir LOWTHIAN BELL said he was in that position with regard to his connection with the chrome-lined open-hearth furnace which other gentlemen had so pathetically described themselves to have passed through when they were merely in the experimental stage. He was sorry that he was called out of the room, but he heard, he thought, Mr. Paul mention the fact that phosphorus always disappeared before the carbon.

Mr. PAUL: No; they go together.

Sir LOWTHIAN BELL said that, according to his investigations, that was equally incorrect, because, to the best of his recollection, the first substance to disappear was the silicon, and it was lost so rapidly that the effect might be almost considered as instantaneous. He was speaking from recollection, because it was some few years since he had the matter before him. In puddling, and in the old refinery, the phosphorus was then removed, and this was essentially the case in the process he had described as the purifying process, in which the phosphorus disappeared almost simultaneously with the silicon. He was under the impression that in the basic process this was also the order of the disappearance of the metalloids, but it was different in the acid Bessemer converter, where the phosphorus was retained. He would first say that he agreed with what Mr. Paul had said about the slag in the open-hearth furnace and the basic process generally, namely, that the presence of lime must be rather looked upon as playing a secondary part in the removal of the phosphorus. In his opinion, in each case, whenever they removed phosphorus it had been in the first instance through the instrumentality, not of the lime in it, but of the oxide of iron in the bath. That was, at least, the opinion he had come to after considering the question very carefully.

Mr. THIELEN said he must have been misunderstood by his friend Mr Richards. Mr. Richards spoke about the use of the Lorraine or Luxembourg ore in the open-hearth furnace. Mr.

Thielen, however, had spoken of Lorraine ore only in connection with the Bessemer basic process, and not as connected with the open-hearth furnace. He said that they were only using in Germany either the scrap process with pig iron, or the pig-iron process by itself, but not the different processes combined. Mr. Head had mentioned something as to the German manufacture of basic Bessemer steel. He was sorry he did not exactly hear what that gentleman had said, but he thought he told them that in Germany they were fulfilling the requirements of Lloyd's test with Bessemer basic steel. Was not that the case?

Mr. JEREMIAH HEAD said he was referring to what Mr. Martell had said, namely, that basic steel was produced in Germany and Belgium which fulfilled all his requirements. He did not think he mentioned whether it was by the basic Bessemer or by the basic Siemens process.

Mr. GILCHRIST: Basic Siemens, he said.

Mr. JEREMIAH HEAD: Then it was not Bessemer basic.

Mr. JOSEPH COOPER remarks through the Secretary, that from his experience of lining and starting these furnaces, he had found it advisable to have the side walls built up from the bottom plates (in the same way in which an acid furnace is prepared), with a course of bricks laid on the floor, and the roof put on before the basic lining was commenced. A really good and sound basic lining was made by following the course usually adopted in burning in a sand bottom; but in the basic lining it was necessary to carry up the banks higher—say up to the level of the foot of the door arches, so that the silica walls were out of the reach of, and thereby well protected from, the slag of the charge, which alone could injure them. By adopting this course no neutral joint was needed, as the silica walls would not suffer by the basic material being placed against them. Regarding the most suitable iron for basic steel-making, almost any kind of iron would answer the purpose; providing it contained no more than 0·1 per cent. of sulphur with silicon below 1·5 per cent. Where cheap phosphoric pig was not directly at hand, a

mixture of old railway chairs or similar cast-iron scrap, with about an equal quantity of smith's scrap or disused iron rails, an excellent charge was made up, and was easily and quickly converted into good soft steel for plates, bars, &c. Such a charge had the advantage of cheapness, and was readily procurable.

The PRESIDENT proposed a vote of thanks to Mr. Darby for his excellent paper. He would, in passing, say that his own experience with a round furnace was very similar to that of Mr. Richards. They were working the round furnace at the present moment, and all he could say was that he wished they were not. When they rebuilt the furnace, he should follow the lines indicated by Mr. Richards. He would also observe, with reference to Mr. Stoddart's remarks as to his difficulties in producing steel of a sufficient tensile strain, that he thought it would be wise to confine his competition to the established makes of steel. He quite agreed with Mr. James Riley, that it was a mistake, in making steel in masses for forgings, and axles, and similar descriptions of steel, to go in the direction of excessive softness. He thought the hard steel with a reasonable amount of ductility was likely to be much more serviceable, and to be much less likely to develop hidden flaws. If they got a steel forging too soft in its character they frequently had an initial flaw developed, which led ultimately to disaster. They should make a good, sound, reliable quality of hard steel with a fair amount of ductility, and they would produce steel which would be much more serviceable for those purposes at least. They were much indebted to Mr. Darby, and he was sure they would unanimously accord to him a vote of thanks.

The motion was unanimously adopted.

Mr. DARBY, in acknowledging the vote of thanks, said he would reply first of all to Mr. Wailes. He had tried burning in the bottom, but had not succeeded, and had returned to the old method of ramming, which he found to answer fairly well. Mr. Martin had mentioned the question of welding. He (Mr. Darby) found that the basic steel welded freely; in fact, there were very few samples that did not weld. The ores used in making

the pig iron were chiefly tap cinder and Northamptonshire ores. The average consumption of coke mentioned—22½ cwt.—was over a period of three months. In reply to Mr. Gilchrist, he might say that they made 14 or 15 charges per week, of 12 tons each, from a consumption of 70 per cent. of pig and 30 per cent. of scrap. He drew attention to the fact that he found that the oxide in the slag referred to by Mr. Paul should be exhausted before the charge was tapped. He thought it was important to get the oxidising slag at first, but at the latter part of the charge it was important that the oxide should be exhausted as far as possible.

Mr. PAUL: Providing the oxidation of the iron could be prevented?

Mr. DARBY: Providing the oxidation of the iron could be prevented. He did not think there were any other remarks he had to make, but simply to thank the members for listening to his paper and criticising it.

Sir LOWTHIAN BELL said he must apologise for having made an obvious mistake with reference to the order in which phosphorus left the basic converter; for he found that he was in error in having included the basic converter in the order in which the metalloids were removed. His observations could not, under any circumstances, apply to the acid process, because, as was well known, the phosphorus remained unaffected. It was true with regard to the purifying or washing process, the refinery, and the mechanical and hand-puddling furnaces. The carbon there was the last to leave the iron. In a basic Bessemer converter the phosphorus was undoubtedly carried off before the carbon.

The following paper was then read:—

ON THE PROGRESS MADE IN THE GERMAN IRON INDUSTRY SINCE THE YEAR 1880.

By E. SCHROEDTER, Düsseldorf.

When in the year 1880 the Iron and Steel Institute held its autumn meeting in Düsseldorf, and at the same time visited the industrial exhibition held there, the members were presented with two papers giving them an idea of the importance of the German iron trade. One of these was by Dr. Wedding on "The Iron Industry of Germany,"* and the other was by Mr. J. Schlink on "Pig Iron Making in Germany." †

Since that time, nearly ten years ago, no further communication on the same subject has been presented to the Iron and Steel Institute, and the author has consequently gladly availed himself of the flattering invitation of the Secretary of the Institute to draw up a report on the progress made in the meantime in the German iron industry. He begs for indulgence if the following notes are not exhaustive, and undertakes not to weary his audience by repeating any of the information contained in the two important papers mentioned above.

In the first place, it must be noted that the strength acquired by the German iron industry was concurrent with the foundation of two societies closely bound up with it. One of these societies is the *Verein deutscher Eisen- und Stahlindustrieller* (founded in 1877), with its office in Berlin, and the other is the *Verein deutscher Eisenhüttenleute* (founded in its present form in 1880), with its office in Düsseldorf. Both societies work hand in hand, the latter dealing chiefly with technical questions, and the former with economical and statistical ones. In order to more effectively carry out its purpose, the *Verein deutscher Eisen- und Stahlindustrieller* has been divided into six groups, according to the geo-

* *Journal*, No. II., 1880, p. 451.
† *Ibid.*, p. 528.

graphical position of the principal iron-producing districts. The following details are largely based on the records compiled by Dr. Rentzsch, the able secretary of this society, since they appear best suited for judging the state of the industry as a whole, and the fluctuations of the various districts.

Before, however, we enter into the details of the history of the German iron industry, it will not be out of place to cast a side-glance on the activity of coal-mining in the German Empire.

The output of *coal* in Germany since 1880 has been as follows:—

	Metric Tons.
1880	46,973,566
1881	46,688,161
1882	52,118,595
1883	55,943,004
1884	57,233,875
1885	58,330,398
1886	58,056,598
1887	60,333,984
1888	65,321,834

Last year the production of the Dortmund mining district (the Ruhr coalfield) amounted to 33,223,614 metric tons, or 50·8 per cent. of the total output of the Empire.

The conditions for the production of *coke* have changed but slightly during the last ten years. It cannot be denied that success has attended the efforts to make coke from the coal raised in Silesia, and in the Saar coalfield, where the coal has been found not well suited for coke-making. The quality of the coke there produced has constantly improved. But the chief weight of the coke made is borne by the Ruhr coalfield, where the coal coked has amounted during the last ten years, as in previous years, to from 17 to 19 per cent. of the total amount treated. The Ruhr coalfield also exports not inconsiderable quantities of coke. It covers in round numbers 42 per cent. of the requirements of the highly developed iron-smelting districts of Luxemburg and German and French Lorraine, which may be estimated at some two millions of tons yearly.

In the construction of the coke-ovens, improvements are being constantly made. The firm of Dr. C. Otto & Co. in Dahlhausen, on the Ruhr, has in successful operation 610 coke-ovens of the Hoffmann type (German patent, No. 18,795), in which the by-

products are recovered. Besides these, 240 coke-ovens of the same type are being built, whilst 100 coke-ovens of the Hüssener type (German patent, No. 20,196) are in use, and old beehive-ovens have been successfully adapted to regenerative working. At the Shamrock colliery, at the present time, fifty-six of these ovens are in operation, and it is intended to alter other ovens in the same way. For English conditions, on account of the large number of beehive-ovens in use, this method is worthy of consideration.

With reference to the Lürmann oven, Mr. Blauel * reports that in it he has, without difficulty, obtained 80 per cent. of hard and dense coke from a mixture of 40 to 45 per cent. of meagre anthracitic coal, and 60 to 55 per cent. of good bituminous coking coal.

The production of *iron ore* was as follows:—

Year.	In Germany.	In Luxemburg.	Total.	Value.
	Metric Tons.	Metric Tons.	Metric Tons.	£
1880	5,065,176	2,173,664	7,238,840	1,722,675
1881	5,438,919	2,161,882	7,600,801	1,804,276
1882	5,786,449	2,476,805	8,263,254	1,959,083
1883	6,180,641	2,575,976	8,756,617	1,965,935
1884	6,554,342	2,451,454	9,005,796	1,877,155
1885	6,509,379	2,648,490	9,157,869	1,695,671
1886	6,051,579	2,434,179	8,485,758	1,482,170
1887	6,701,395	2,649,711	9,351,106	1,700,263
1888	?	?	10,664,789	1,998,200

In comparison with the valuable statements made by Mr. Schlink,† some not inconsiderable alterations in the production of ore will be noticed, in consequence of the invention of the basic Bessemer process. Above all, it may be noted that the extensive deposit of Minette in Luxemburg and Lorraine, which formerly had but a limited use, has attained a high and constantly increasing estimation.

According to Mr. A. Jäger ‡ Minette consists of fine oolitic grains of brown hæmatite, cemented together by calciferous, argillaceous, or siliceous masses. Its chemical composition varies

* *Stahl und Eisen*, 1889, p. 35.
† *Journal of the Iron and Steel Institute*, 1880.
‡ *Stahl und Eisen*, 1881, p. 174.

considerably, the limits being shown in the following analytical results:—

	Per Cent.		
Iron	19·36	to	58·735
Silica	0·807	„	45·18
Alumina	0·95	„	19·20
Lime	0	„	46·02
Magnesia	0	„	8·40
Manganese	0	„	1·70
Phosphorus	0	„	1·964
Sulphur	0	„	1·84

Minette with less than 27 per cent. of iron is not regarded as suitable for smelting purposes. Usually a mixture is employed, which renders the addition of lime as flux unnecessary, and yields 28 to 34 per cent. of iron. For export, the higher grade ores are naturally preferred, and the average yield of the Minette exported to the Lower Rhine and Ruhr may be taken at 38·5 per cent. of iron with about 10 per cent. of water.

The amount of available ore in the Luxemburg-Lorraine deposit is estimated by Mr. Jäger at 2400 million tons. In other words, it is quantitatively one of the most important deposits known in Europe, being exceeded in size only by the clay iron ore deposits of Cleveland.

The total cost of production at some of the principal mines in 1881 was found by Jäger to be 10d. to 1s. 2½d. per ton. At that date it was, however, higher at other mines, and may now have on the whole slightly increased.

The increase in the value of the Luxemburg-Lorraine deposit has been considerably influenced by the fact that in the Rhenish-Westphalian district there has been want of ore for several years. The bog iron ore fields of that district, and of adjacent regions, are partially worked out; black-band is scarce, and the spathic ore and brown hæmatite of the Siegerland, of which only certain qualities can be used, must be raised from continually increasing depths, whereby the cost is considerably increased. The old spoil banks of cinder, which have found an unexpected utilisation for the production of basic pig iron, are also almost exhausted, and the supply is now limited to the slag produced in current working.

Schlink * calculates that in Prussia, for the production of the

* *Stahl und Eisen*, 1888, p. 148.

2,563,027 tons of pig iron reported in 1886, not less than 2,852,100 tons of ore were wanting, and this was covered partly by slags and partly by imported foreign ores.

Of the foreign ores imported (see table at the end of this paper), the Spanish hæmatite ores and the Dutch bog iron ores are the chief factors.

In the supply of ore for the blast furnaces of Upper Silesia no special change has occurred. In the year 1887, in that district, forty-eight iron ore mines were productive, the value per ton of ore being 3s. 8d.

The production of *pig iron* in Germany, inclusive of Luxemburg, was as follows:—

Year.	With Charcoal.	With Coke and Mixed Fuel.	Total.	Increase or Decrease.
	Tons.	Tons.	Tons.	Per cent.
1880	45,319	2,683,719	2,729,038	...
1881	44,564	2,869,445	2,914,009	+ 6·8
1882	42,230	3,338,576	3,380,806	+16·0
1883	42,622	3,427,097	3,469,719	+ 2·6
1884	40,032	3,560,580	3,600,612	+ 3·7
1885	40,186	3,647,248	3,687,434	+ 2·4
1886	32,893	3,495,765	3,528,658	− 4·3
1887	23,150	3,931,263	3,954,413	+12·0
1888	19,748	4,238,723	4,258,471	+ 7·7

In the year 1888, the production of the different kinds of pig iron was as follows:—

Forge pig iron and spiegeleisen	2,064,016 tons,	or 48·8 per cent.	of the total production.
Bessemer pig iron	395,878 ,,	9·3 ,,	,,
Basic pig iron	1,253,308 ,,	29·5 ,,	,,
Foundry pig iron	516,282 ,,	12·4 ,,	,,

The following table shows the distribution of the pig iron production amongst the various districts:—

Description.	Westphalia, Rhineland, exclusive of Saar District.	Silesia.	Saxony and Thuringia.	Prussian Saxony Brandenburg, and Hanover.	Bavaria, Wurtemberg, Luxemburg, Hessen, Nassau Alsace.	Saar District and Lorraine.
Forge pig and spiegel—	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1883 . . .	40·8	15·8	0·3	1·9	19·3	21·9
1886 . . .	44·9	17·3	0·1	0·6	12·3	24·8
1887 . . .	40·5	15·6	0·2	0·4	16·5	26·8
1888 . . .	41·5	15·1	0·4	0·2	16·0	26·8
Foundry pig iron—						
1883 . . .	41·2	5·0	4·1	5·2	33·2	11·3
1886 . . .	25·8	5·8	1·2	3·0	41·9	22·3
1887 . . .	36·3	4·3	0·6	6·2	34·0	18·6
1888 . . .	37·2	3·9	0·8	6·9	35·0	16·2
Bessemer pig iron—						
1883 . . .	86·9	7·4	2·3	0·0	3·5	0·0
1886 . . .	89·9	4·5	0·8	0·0	4·8	0·0
1887 . . .	88·2	5·4	1·7	0·0	4·7	0·0
1888 . . .	84·9	7·1	3·0	0·0	5·0	0·0
Basic pig iron—						
1883 . . .	53·1	0·0	0·0	16·8	15·1	15·0
1886 . . .	45·2	5·1	0·0	11·3	16·9	21·5
1887 . . .	46·3	4·8	0·0	9·8	19·6	19·5
1888 . . .	44·8	5·9	0·0	9·0	20·4	19·9
Total production—						
1883 . . .	49·5	11·6	0·9	3·5	17·5	17·0
1886 . . .	48·3	11·2	0·3	3·9	16·0	20·3
1887 . . .	46·8	10·1	0·4	3·7	18·2	20·8
1888 . . .	46·0	10·2	0·6	3·6	18·6	21·0

The following table shows the condition of the *blast furnaces* during the years 1880-1887:—

Year.	No. of Blast Furnaces.	In Blast.
1880	314	246
1881	313	251
1882	316	261
1883	318	258
1884	308	252
1885	298	229
1886	285	215
1887	271	212

It is thus seen that while the production of pig iron from the

year 1880 to 1888 increased from 2,729,038 to 4,258,471 tons, or roughly by 56 per cent., the number of furnaces in blast decreased in the same period from 246 to 212. The mean daily capacity per furnace has consequently increased from 30·8 to 55·8 tons.

In considering the latter figure, it must be remembered that a number of smaller blast furnaces, especially charcoal blast furnaces in Nassau, in the Siegerland, Thuringia, &c., are included, and that the capacity of the Upper Silesian blast furnaces (which numbered 46 in 1887), that are also included, does not average more than 41·2 tons.

In the great producing areas, Rhineland, Westphalia, Lorraine, and Luxemburg, the mean capacity of a blast furnace in each 24 hours is 80 to 120 tons, according to the grade of iron produced and the nature of the ore smelted. The consumption of coke for these furnaces may be taken as 0·9 to 1·0 ton per ton of pig iron. In Upper Silesia, on the other hand, the consumption of coke in 1887 averaged 1·650 ton per ton of pig iron.

All the larger blast furnaces have fire-brick hot-blast stoves, the preference being almost universally given to the Cowper system of applying the Siemens regenerative principle. Several cases have come under the author's notice in which hot-blast stoves of other types have been demolished after working for longer or shorter periods, and have been replaced by Cowper stoves. These stoves have been provided for some years past by Fritz W. Lürmann of Osnabrück with a special arrangement for igniting and burning the gases, which has been found to answer admirably.

The Ilsede (Hannover) blast furnaces are unequalled in their efficiency. The consumption of coke at those works for making basic pig iron with 2·9 per cent. of phosphorus, 2·38 per cent. of manganese, and 0·1 per cent. of silicon, is 0·851 ton per ton of pig iron. The total make of the three furnaces during 1888 amounted to 116,098 tons. The daily production of No. 3 blast furnace was 158 tons; the workmen's wages amounted to 2s. 6d. per ton; and the total cost of production was not more than 23s. per ton.

The production of *finished iron and steel* was as follows:—

Year.	Weld Iron.	Ingot Iron.
	Tons.	Tons.
1880	1,358,470	660,591
1881	1,421,792	897,425
1882	1,586,153	1,074,806
1883	1,571,410	1,060,596
1884	1,592,961	1,188,492
1885	1,504,972	1,202,099
1886	1,415,611	1,376,350
1887	1,513.058	1,688,809
1888	1,547,357	1,785,354

The production consisted of the following classes:—

Description.	1887.		1888.	
	Tons.	Value.	Tons.	Value.
Weld iron:—				
a. Blooms, rails . .	69,163	£233,900	79,368	£292,900
b. Cement steel . .	...	...	74	900
c. Manufactures . .	1,443,895	8,275,800	1,467,915	9,016,250
Ingot iron:—				
a. Ingots . . .	85,746	320,250	102,944	463,000
b. Blooms, billets . .	488,109	1,857,100	457,524	1,880,400
c. Manufactures . .	1,114,954	7,767,500	1,224,886	8,575,550

From this table it may be seen that although the threatened complete ousting of weld iron, by the invention of the dephosphorising process, has not occurred, yet its production during the last decade has stagnated, whilst the production of ingot iron during the same period has been nearly tripled.

The number of puddling furnaces is roughly 2200, of which 60 to 85 per cent. are in regular operation. In the construction of these furnaces no essential change has been effected. In Duisburg, double furnaces, designed by Karl Küpper, and at Friedenshütte, in Upper Silesia, Pietzka's revolving puddling furnace, have been successfully adopted.

The changes in the ingot iron (steel) works are much greater. These are chiefly due to the almost general introduction of the production of steel from phosphoretted pig iron. The production of basic pig iron in the year 1888 is stated above to have amounted to 1,253,308 tons, and as Mr. Gilchrist gives the world's produc-

tion of basic steel as 1,984,184 metric tons, the share of Germany may be taken as 60 per cent.

It is marvellous with what certainty the process is carried out. By mechanical and chemical tests, untiringly conducted, the steel-works have learnt to supply blocks, rails, billets, bars, &c., of excellent and always uniform quality, as required.

In many cases the pig iron is treated direct from the blast furnace. Soaking-pits are largely used, and the consumption of coal is usually very slight.

Of basic converters I venture to give the following list, without vouching for its absolute accuracy:—

Hoerde Co., Hoerde	4	converters each of	10 tons
Rhine Steelworks, Meiderich	3	„ „	7 „
Bochum Co., Bochum	3	„ „	5 „
Gutehoffnungshütte, Oberhausen	4	„ „	10 „
Union, Dortmund	3	„ „	10 „
Steelworks Hoesch, Dortmund	3	„ „	10 „
Phœnix, Ruhrort	3	„ „	10 „
Aachenerhütte, Rothe Erde	3	„ „	10 „
Hasper Steelworks, Haspe	3	„ „	3½ „
Stumm Bros., Neunkirchen	3	„ „	10 „
De Wendel, Hayinge	4	„ „	6 „
Dudelinger Ironworks Co. (Luxemburg)	4	„ „	10 „
Peine Works, Peine	4	„ „	10 „
Friedenshütte, Upper Silesia	3	„ „	10 „
Konigshütte, „ „	2	„ „	10 „
„ „ „	1	„ „	7½ „
Maximilianshütte (Bavaria)	3	„ „	5 „
Völklinger Ironworks (Saar)	4	„ „	9* „

It may be added that some of the above-mentioned converters are worked alternatively under the acid process.

Lastly, the *imports* and *exports* of ores, pig iron, iron and steel manufactures, and machinery, may be summarised as follows:—

Imports.

Year.	Iron Ore.	Pig Iron.	Manufactures.	Machines.
	Tons.	Tons.	Tons.	Tons.
1881	626,175	250,576	41,041	25,548
1882	783,177	291,698	41,451	31,209
1883	800,373	283,992	43,075	34,081
1884	980,442	272,269	48,315	39,978
1885	853,007	223,466	45,308	37,145
1886	812,676	169,728	41,849	30,934
1887	1,036,217	164,015	53,867	35,042
1888	1,163,372	224,900	47,821	39,912

* Under construction.

Exports.

Year.	Iron Ore.	Pig Iron.	Manufactures.	Machines.
	Tons.	Tons.	Tons.	Tons.
1881	1,443,278	353,247	782,445	66,601
1882	1,621,182	279,210	787,026	84,878
1883	1,886,450	351,517	788,614	92,374
1884	1,898,471	297,116	763,957	84,287
1885	1,771,158	276,764	772,655	72,912
1886	1,831,649	345,318	864,838	72,331
1887	1,744,551	312,977	947,319	79,854
1888	2,211,810	195,012	858,421	76,819

The exports, on the whole, show an increase up to 1887, and then experience a slight decrease. This is due, on the one hand, to the fact that the demand on the world's market, especially for rails and wire by the United States, has become less, while several countries, as, for example, Russia, have almost entirely closed their market; and, on the other hand, to the fact that the home consumption has increased very considerably, at, for the most part, lucrative prices. In this connection, it must not be forgotten that the German ironmasters have endeavoured for a number of years, at the expenditure of large sums of money from a common fund, to open up new fields for the application of iron, more especially in building construction, as a substitute for stone and wood; and that they are by degrees reaping the fruit of these endeavours.

On the whole, the retrospect presented by the years considered in this paper is highly gratifying for the German ironworks; a satisfactory and continuous development is shown, which also awakens good hopes for the future.

DISCUSSION.

Mr. THIELEN (Ruhrort) said he wished to hand in a paper* which had been prepared for distribution among the master-builders in Germany, in order to convert them from users of wood to users of iron. They had been very successful in this effort, for the quantity of iron now used in Germany for building purposes was something enormous. Copies of the paper in question had been sent to the more important builders all over the country.

The PRESIDENT proposed a vote of thanks to Mr. Schrödter for his excellent paper. It would require careful consideration at home, and would prove valuable for reference as to the condition and development of the German iron trade. The paper Mr. Thielen had handed in referring to iron construction was a paper which the Iron Association of Germany spread widely amongst the architects and constructors of Germany with a view to develop markets for their products. He thought that that was a very excellent suggestion, which should be taken into consideration in England, and that they might endeavour—very modestly, no doubt—to instruct architects and others in the proper application of iron and steel for constructive purposes. Mr. Thielen had stated that the distribution of the paper had materially developed the consumption of steel and iron in Germany for those purposes. There was a very gratifying fact mentioned in the paper, namely, that the German iron trade was finding a good trade at home at lucrative prices. It was said that that was highly gratifying to the German ironworks, but he need scarcely say that it was equally gratifying to the English iron trade to hear that the Germans were making that excellent market at home.

The vote of thanks to Mr. Schrödter was carried by acclamation.

The following paper was then read:—

* The work in question is entitled "Musterbuch für Eisen construction."

ON THE INFLUENCE OF COPPER ON THE TENSILE STRENGTH OF STEEL.

By Dr. EDWIN J. BALL and Mr. ARTHUR WINGHAM.

It has long been a matter of discussion whether true alloys of copper and iron can be produced, and great divergence of opinion has existed as to the influence exerted by small quantities of copper on the mechanical properties of iron and steel. As evidence on this point, attention may be drawn to the views expressed by Mushet, Rinmann, Berthier, Karsten, Willis, and Percy, the general opinion appearing to be that copper renders iron and steel red-short. Jars,* writing in 1774, observes, "It is generally thought that copper is a pest for iron," but he adds that he had been told by Cramer, that small quantities of copper had been found by him to improve the quality of iron, and that even 1 per cent. could be added without destroying the welding power of that metal. Such experiments as have hitherto been made in connection with this subject were but imperfectly supported by analytical evidence as to the composition of the alloys produced, but the earlier of the experiments above referred to were made before the necessity of submitting metals to rigorous mechanical tests was well understood.

This divergence of opinion led us to believe that it would be interesting to obtain some definite results connected with this subject. A series of experiments was therefore instituted to ascertain the effect produced by varying quantities of copper on the tensile strength of steel. In beginning these experiments, it appeared desirable to prepare, in the first place, an iron rich in both copper and carbon, and then to alloy this with a metal containing but little carbon. The metal chosen for the latter purpose was a variety of basic Bessemer steel, the analysis of which was as follows:—

Basic Bessemer Steel.

	Per cent.
Copper	none
Carbon	0·133
Manganese	0·284
Silicon	0·002
Phosphorus	trace
Sulphur	0·060

* *Voyages Métallurgiques*, Lyons, 1774, vol. i. p. 4.

The iron, rich in copper, was produced by melting pig iron, and then adding to the molten metal oxide of copper. The carbon and silicon acted as the reducing agents for the cupric oxide, and the copper was thus introduced into the iron by a "reaction," and not by simple solution. A part of the other impurities in the pig iron was also burnt out in this manner, and a metal (A) was obtained which had the following composition:—

Metal A.

	Per cent.
Copper	7·550
Carbon	2·720
Manganese	0·290
Silicon	0·036
Phosphorus	0·130
Sulphur	0·190

This metal was bright, white in colour, crystalline, and very hard, but it did not offer any great resistance to impact. Varying quantities of it were then melted down with the basic Bessemer steel previously mentioned.

The products of these fusions were allowed to cool very slowly, the crucibles in which the fusions had taken place being permitted to remain in the furnace until quite cold. Test-pieces, 1 inch by $\frac{1}{4}$ inch by $\frac{3}{16}$ inch, were then cut, and submitted to tensile tests in a multiple lever testing machine, the test-pieces being first carefully annealed.

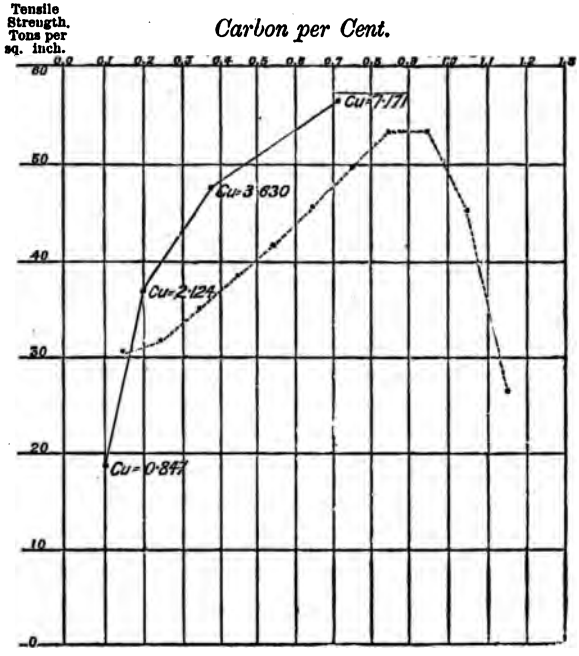
In the alloys produced in this manner the percentages of carbon and of copper necessarily increased simultaneously. It would, of course, have been desirable to test the influence of varying quantities of copper on steels which contained gradually increasing percentages of carbon, but such experiments would entail a lengthened investigation, and we have therefore considered it sufficient, in this preliminary examination, to obtain evidence as to the influence of copper on iron in the presence of gradually increasing quantities of carbon, which might form a basis for a further examination of the question.

The following table shows the percentages of copper and of carbon in the metals tested, and the results of the tensile tests of the various specimens:—

Test-Piece.	Copper.	Carbon.	Tensile Strength.
No.	Per cent.	Per cent.	Tons per square inch.
1.	0·847	0·102	18·3
2.	2·124	0·217	36·6
3.	3·630	0·380	47·6
4.	7·171	0·712	56·0

The total elongation of the test-pieces was also noted, but owing to their small size the results are not trustworthy. The elongations observed, however, were as follows:—Test-piece, (1) 10 per cent.; (2) 5 per cent.; (3) 5 per cent.; (4) showed no visible extension, or the extension was but very slight.

In the following table are shown, in the form of a curve, the tensile strengths given above, as well as those which are considered by Mr. R. Gatewood * to represent the strengths of ordinary steels of varying degrees of carburisation, the latter curve being shown by dotted lines:—



It will be observed that the tensile strengths of the specimens

* *Journal of the Iron and Steel Institute*, 1887, vol. i. p. 444.

containing copper are greater than those of the specimens in which no copper is present. Where the turning-point of the curve would be in the case of the cupriferous series, we are unable to say, as other samples which were prepared, and which contained more carbon than the above, were so hard that test-pieces could not be cut. That copper increases the tensile strength of iron is also apparent from the following results:—

Description.	Copper.	Carbon.	Tensile Strength.
	Per cent.	Per cent.	Tons per square inch.
Original steel . . .	...	0·133	29·0
Test-piece 5 . . .	4·10	0·183	43·2
Test-piece 6 . . .	4·44	trace	34·3

This latter metal did not, however, appear to be perfectly homogeneous, and it was observed throughout these experiments that the simultaneous presence of carbon appeared greatly to assist in the more intimate association of the copper with the iron in which it was dissolved.

Observations of the fracture showed that of test-piece 1 to be somewhat fibrous, whilst those of 2 and of the remaining samples were highly crystalline. The fracture of sample 6, which contained no carbon, was very irregular, the metal being of a bright grey colour, and highly crystalline. The fracture of specimen 4 was very finely granular and close.

Besides determining the tensile strengths, forging tests were also made. Some of the specimens, comparatively poor in copper and carbon, appeared to forge fairly well both cold and hot, and this was the case with specimens 1, 2, 3, and 5. No. 4 forged well in the cold, but was red-short, which is to some extent in accordance with the views expressed by the older writers. The results cannot, however, be considered very reliable, owing to the small quantity of the material that was at our disposal for the purpose of these tests. The principal effect that the presence of copper appears to exert on iron and steel is to render it extremely hard. This was peculiarly evident in the case of specimen 6, which was free from

carbon, but contained 4·44 per cent. of copper, and was so hard that it could scarcely be cut by a good hack-saw. Owing to this great hardness, and to the comparatively good results of the forging and tensile tests, we hope that further tests of the crushing strengths of these metals may lead to the results being of interest from a practical point of view.

The opportunity afforded by the preparation of the metal A was taken for observing the order in which the carbon, sulphur, and silicon originally present in the pig iron were eliminated by the oxygen of the cupric oxide added, the percentage of sulphur in the metal having been largely increased for the purpose of this experiment, which consisted in melting the iron in a graphite crucible, and then making successive additions to it of cupric oxide. After each addition of the oxide the metal was poured, a sample taken for analysis, and the remainder charged into the crucible again and remelted, a further addition of cupric oxide being then made.

The following table shows the composition of the pig iron used, as well as that of the samples taken after each successive addition of cupric oxide:—

Description.	Silicon.	Carbon.	Sulphur.
	Per cent.	Per cent.	Per cent.
Pig iron	1·02	2·60	1·44
First sample . . .	0·55	2·32	1·27
Second sample . . .	0·10	2·02	1·12
Third sample . . .	0·05	1·77	1·18
Fourth sample . . .	trace	0·61	1·08
Fifth sample . . .	trace	0·34	0·85

It will be observed that whilst the silicon was rapidly oxidised, the carbon was only appreciably attacked after nearly the whole of the silicon had been eliminated; and, further, that the percentage of sulphur was not greatly affected till most of the carbon had been burnt off. This diminution in the percentage of sulphur may, however, to some extent be accounted for by the dilution of the pig iron by the copper reduced from the cupric oxide.

From a general consideration of the results of our experiments it would seem that within certain limits copper does not prejudicially affect the mechanical properties of steel, and this to some

extent agrees with the theory recently put forward by Professor Roberts-Austen,* and supported by much experimental evidence, that small quantities of a metallic impurity only exert a deleterious effect on a large mass of another metal if the atomic volume of the impurity is greater than that of the metal in which it is hidden; and that if the atomic volume is either about the same or smaller, it will either exert no appreciable deleterious effect, or else act as an improver. The atomic volume of copper is nearly the same as that of iron. In our experiments, however, the percentages of copper were considerably higher than those which Professor Roberts-Austen contemplates.

In view of the fact that these experiments were of necessity conducted on a small scale, we submit their results to the Iron and Steel Institute with some diffidence; but we publish them in the hope that some one with greater industrial facilities at his command will submit the question to a more complete examination—an undertaking which our few preliminary experiments would appear to justify.

* *Proceedings of the Royal Society*, vol. xliii. (1888), p. 425.

DISCUSSION.

Mr. F. STUBBS said that some years ago he had had a sample of steel submitted to him which was said to have the very peculiar property of being burnt, and yet after burning to be in quite as good a condition as before. To prove that, he took a piece of steel, and raised it to a burning heat in an ordinary smith's hearth, he struck the piece against the anvil, and, of course, scattered the burnt steel in all directions; he took the pieces up again, re-heated them, and welded them together, and from the burnt steel produced a chisel that gave quite as good results as the original piece of steel. On a careful analysis of the steel, he found that the only element that differed from those of ordinary steel was the presence of about ½ per cent. copper. It appeared to him that the presence of copper to that extent gave it this peculiar property, of preventing the oxidation of the steel on being subjected to a burning heat. He had made one or two experiments by adding copper to a charge of steel in the crucible, and found that it gave very similar results. He thought the subject was well worth following up, as it appeared to him that copper to that extent in steel had the power of preventing oxidation when subject to very high temperatures.

Mr. HILARY BAUERMAN said that the author's conclusions were similar to those obtained in an investigation made by A. Wasum, at Bochum, in 1875, an abstract of which would be found in the *Proceedings of the Institution of Civil Engineers* (vol. lxii. p. 400). He observed that steel containing 0·862 per cent. of copper was perfectly workable in a rail rolling mill. The real offender in such cases seemed to be sulphur, which was likely to be present when copper was introduced into the metal, as iron ores, when cupriferous, generally contained copper as sulphide. The author had given some very interesting facts in the paper, but he thought it would be well in those cases, with metals which alloyed with such difficulty as iron and copper, to use some rather more refined test to find out whether the distribution was uniform; that was, some physical process of grinding down and then etching,

to find out whether there was a real alloy in the matter. He remembered a case of a very cupriferous pig iron once coming under his notice on Lake Superior some years ago. This was smelted from a dense slaty hæmatite in which a small vein of grey sulphide of copper had passed unobserved, the two minerals being almost exactly similar in appearance. It went into the furnace, and a very remarkable pig iron came out, spotted all over with copper, but there did not appear to be any actual union between the two metals.

The PRESIDENT proposed a vote of thanks to the author of the paper, which was duly accorded.

Dr. BALL, in acknowledging the vote of thanks, referred to the statement made by Mr. Bauerman, and said that, after the paper had been in type, he had been interested in finding a reference to the action of copper on iron, in a book which was published in Paris, by Louis Savot, in 1627, and in which the author mentioned the difficulties that smiths experience in working iron containing copper. Copper, the author stated, rendered iron brittle, and he referred to a still older chemist, Budelius, who mentioned that it rendered iron incapable of being welded. The President, in his address, had pointed out that the question as to the influence of a small quantity of a metallic impurity on iron and steel was now becoming every day more and more important, and it was therefore interesting to find that, as regards the action of copper on iron, the question was considered of importance three hundred years ago. With regard to the question of the possibility of producing true alloys of iron and copper, Mr. Wingham and himself were of opinion that when carbon was present the metal was distinctly far more homogeneous than when no carbon was present. In their preliminary experiments they had attempted to produce such copper-iron alloys, but they arrived at the opinion that when the percentage of copper exceeded certain limits the alloy formed ceased to be homogeneous on cooling. They therefore thought it desirable to introduce the copper in another form, and they did so, as was stated in the paper, by using oxide of copper. The oxide of copper, being reduced *in situ* by the carbon and the

silicon of the pig iron, the copper was introduced into the iron in an atomic form; and when the copper did not exceed certain comparatively small limits the metal seemed perfectly homogeneous. It, appeared, however, to require somewhat careful heating.

The following paper was then read :—

ON UNIVERSAL ROLLING-MILLS FOR THE ROLLING OF GIRDERS AND CRUCIFORM SECTIONS.

By HUGO SACK, Duisburg-on-the-Rhine.

In the face of the multifarious applications and the continuously growing use of girders and similar sections (the value of the imports of this kind of iron into England in 1888 is stated to have been no less than £387,000, and in previous years it was probably of almost similar magnitude),* it is a remarkable fact that the quality of this kind of iron has not as yet attained the perfection which now-a-days generally is required of rolled iron. Whilst all other products of rolling-mills are submitted to the severest tests, yet, with the highly important H iron, people are accustomed to be content with much less strength and a proportionate increase of weight instead, where that is admissible. For bridge-work and other iron structures exposed to strains by sudden shocks, and in cases where safety has to be combined with the least weight, built-up girders are always preferred.

This is because, by the ordinary system of rolling-mills, it is not possible to produce properly worked flanges. The wider and thinner and the less tapered the flanges, the greater becomes the difficulty. This defect can be avoided with channel and sleeper sections by rolling them in a bent state. It makes itself less felt with tees, tee-bulbs, flanged rails, and smaller girders. With heavy H girders it is difficult to mitigate the defect, as will be seen from the following notes:—

The successive sections in the process of rolling girders are like fig. 1. In order that the rolled bar may easily fit into the next groove, the latter is always somewhat wider than the previous one. In this way sections are obtained of increasing width, and it is obvious that under such circumstances no pressure can be exerted upon the outer surfaces of the flanges, and their width cannot be much reduced. Therefore the inner surfaces alone offer a point of attack for reducing their thickness.

* Previous to 1887 no separate records were kept of the imports of girder iron into the United Kingdom. In that year the imports of "girders, beams, and pillars" were 59,206 tons, and in 1888 69,313 tons.—Ed., *J. I. and S. I.*

By this process the rolls must evidently squeeze themselves between the inner surfaces of the flanges.

In fig. 3, which shows a girder between the rolls, the first contact

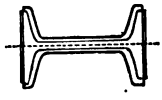


Fig. 1.

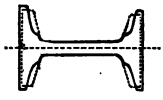


Fig. 2.

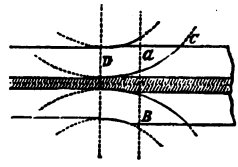


Fig. 3.

takes place at C, and the material is scraped down on the inner face of the flange, the edges of the rolls raising there a ridge, and accumulating material in the corners, as shown in fig. 2, where the dotted lines indicate the previous shape before passing, and the full lines the shape of the section at the intermediate point A—B. Now, the material in the corners must be displaced laterally, that is, across the fibre, thereby weakening the tensile strength of the material. Until the contact of the rolls at the web occurs, we may distinguish two stages: the first, when the roller comes into contact with the flanges and begins to scrape; the second, when the material is piled in the corners and displaced laterally.

Before acting upon the web, which is the third stage, it is clearly to be seen that the flanges have been extended nearly completely whilst the web still preserves its original length. This way of procedure, of course, must produce a great strain in the rolled material, besides considerable wear and tear of the rolls, owing to the scraping-down action. These are great drawbacks to the usual process of rolling girders, and explain why it is so important to use soft iron. Evidently a material which yields easily to the rolls, and which, therefore, is capable of taking up the strains caused by the unequal, and far from simultaneous, extension of its mass, will be best suited for the manufacture of structural sections. Phosphoric iron possesses these qualities in a high degree, and consequently, in spite of its cold-short defects, is largely used for the manufacture of joists. This also explains why the gradual rolling of the girder sections by numerous passes through the rolls will somehow mitigate the evil, for the more rapidly the rolling is effected, the more pronounced the defects

will be. With smaller H sections, a considerable number of grooves can be arranged upon the rolls. In consequence of this fact, they are, as a rule, always of a better quality, but with larger sections a great number of grooves would require a considerable length of rolls, which would be very expensive, and at the same time give trouble in changing them and keeping them in working order. In Belgian and German mills, the large 20″ and 22″ girders of phosphoric wrought iron are roughened down, as a rule, in nine, or eight, or even seven passes. Thus the pile, which is built up to a similar shape, is directly and very rapidly formed without appropriate welding grooves, which implies a doubtful welding of the material, all the more so as the flats in the pile are arranged across the web.

Clearly this rapid rolling process cannot have a good influence. Moreover, these practical difficulties lead to the adoption of sections suitable to the exigencies of rolling, rather than to products capable of resisting the strains which they are intended to bear. A glance at any section-sheet will show that the height of the flanges does not increase in proportion to the width of the web. Apart from the bad distribution of the metal from the point of view of its power of resistance, an evil also lies in the proportionately greater quantity of material removed by the rivet-holes in a low thick flange. Generally, also, the web of large section is much too heavy in proportion, a circumstance which frequently alone suffices to give the preference to a riveted girder. Hence we may see what influences are operating to keep the built-up girder in favour. But we may also recognise the vast field of work that would open itself out to a more perfect system of rolling both iron and steel.

Only small steel girders up to 12″ can now be rolled in the ordinary trains satisfactorily. Although the possibility of rolling larger sections by means of the present methods cannot directly be denied, yet it cannot be seen how they could compete with regard to price. As already mentioned, in order to reduce the pernicious effects of unequal and unsimultaneous stretching, the bar must undergo as many passes as possible, which requires too many housing frames, rolls, and engine power, and, as a consequence, too many expenses. Finally, the products, though faultless in appearance, are still of doubtful value, because the

strains which, during the rolling process, can never be fully avoided, diminish the trustworthiness of these girders.

Consider now the position of the steel industry, the products of which—mainly railway supplies—are subjected to the public tender system, which is not calculated to allow much margin in price, whilst the conditions imposed as to quality are growing in severity, and the trade itself depends upon an irregular demand. It may therefore be assumed that the following communication on a new arrangement of rolling-mills will be welcome.

Evidently, and as many former attempts prove, it is only possible to remedy the inconveniences already stated by a universal mill, consisting of four rolls arranged in one plane.

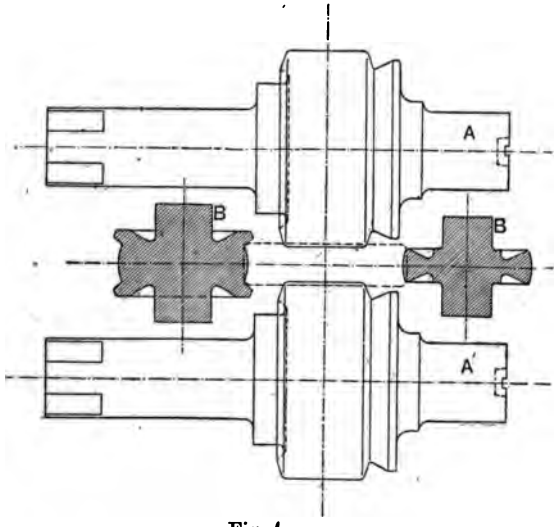


Fig. 4.

Those first attempts, however, could not fulfil the practical requirements of producing sections without fins, and with flanges of equal breadth, and perfectly symmetrically arranged to the web. They could not succeed, because the mills at the time were so complicated in construction, and so difficult to handle, that they could not resist the great strains of the rolling pressure, so that the whole idea of such a system was given up as fruitless.

How far the objections then raised have been met by the arrangements proposed to be submitted to the present meeting of

practical men, must be left to their judgment. It may, however, be mentioned, that the trials which, a few months ago, were made with a Sack universal mill at the works of the Steel Company of Scotland at Newton, at the works of Messrs. David Colville & Sons, Motherwell, and at other places, have proved this mill, as regards the durability and the simplicity of its arrangement, to be a practical success.

As a further advantage, it has been recognised that this mill, as a rule, can without difficulty be combined with any existing reversing or cogging mill, and that sometimes even existing housing frames may be used directly for my mills, whilst still remaining

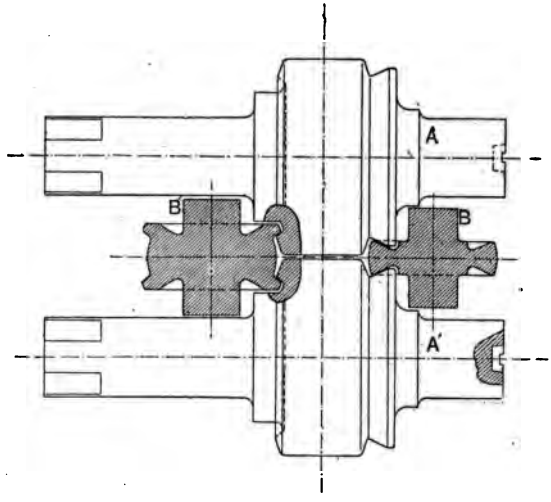


Fig. 5.

serviceable for their former purpose. This may be seen by the wall-drawing, based upon housings of a reversing plant of Messrs. David Colville & Sons, with Sack's arrangement (plate xviii.).

The leading principle of Sack's mill is to drive the horizontal rolls only, the top-roll being adjustable in the usual way by a top-screw gear, by means of which the vertical rolls are moved simultaneously, according to rules, implied by the kind of section to be rolled.

The vertical rolls are loose rolls, the spindles of which are of about two-thirds of the diameter of the horizontal ones, and

strong enough for their purpose. They are driven by the friction against the bar to be rolled, and are carried in housing boxes, A, which are provided with wedge-shaped projections, sliding upon the corresponding surfaces of two pairs of rails, C (fig. 9).

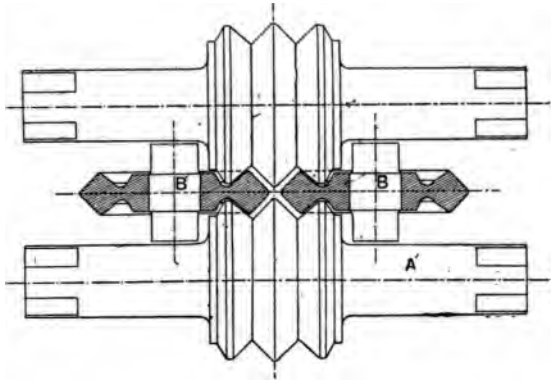


Fig. 6

These rails are inserted into the housing frames, and rest upon the bottom and top carriages of the horizontal rolls. They can be adjusted both in a vertical and in a horizontal direc-

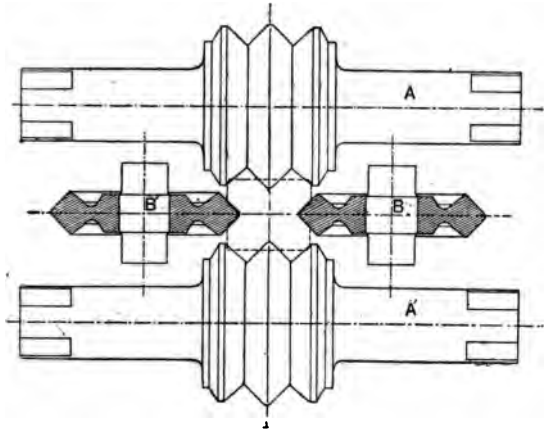


Fig. 7.

tion by means of screws and wedges, which are all easily accessible, even whilst the mill is at work.

The exact adjustment of these rails is a matter of importance,

because it affects the correct correlative position of the vertical rolls against the horizontal ones. Having got into this position, the rolls always remain at a certain proportional distance from each other, suitable for the rolling process, a distance which is

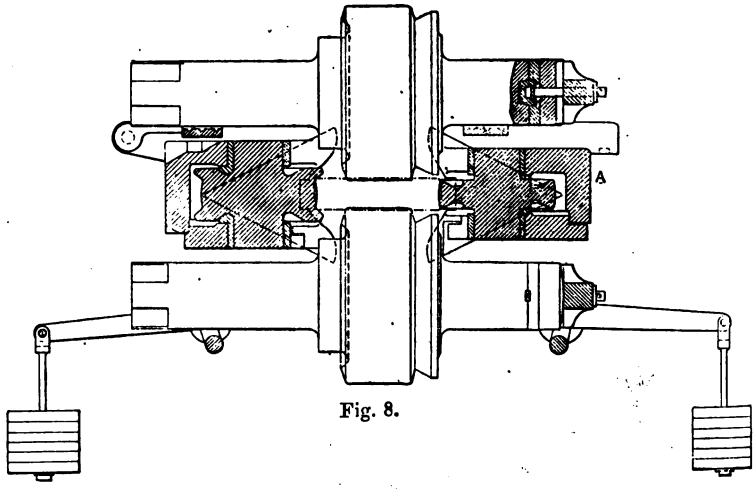


Fig. 8.

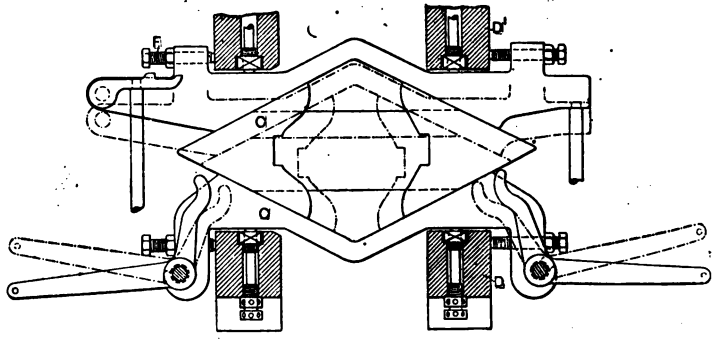


Fig. 9.

influenced by the angle of inclination of the wedged-shaped projections of the bearing-boxes of the vertical rolls. Now, by screwing down the top horizontal rolls, the two top setting rails are also lowered, and force the vertical rolls, by means of the wedges of their housing-blocks, towards each other; and as the top horizontal roll descends, the vertical rolls descend with it, but only through half the distance, so that they always remain central.

This will more clearly be seen from fig. 9, which shows the posi- of the rails, C, at the beginning and the end of rolling, the former tion by full, and the latter by dotted lines. On raising the ws, the vertical rolls, with their carriages, are pulled apart by action of balance-weights, which, however, in large mills are er replaced by steam or hydraulic cylinders.

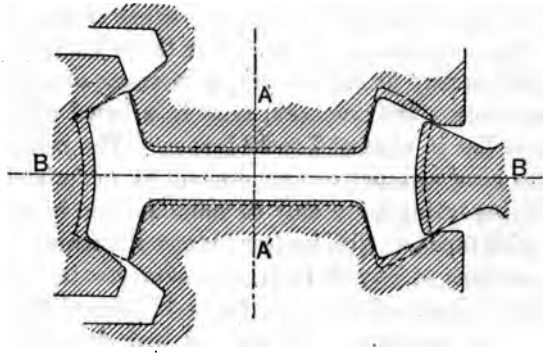


Fig. 10.

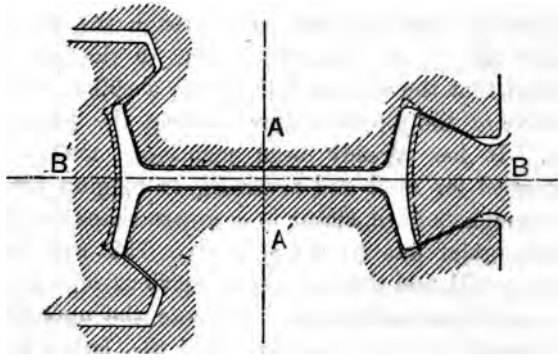


Fig. 11.

The housings of the mill are in no way different from those r usually employed, so that they may serve for all other poses of the plant. Heavy guards are provided, to prevent formation of collars, in case the material should split at the s during the process of rolling. Sack's mill differs from ner designs in one very important point, viz., in so far as

the working surfaces of the rolls cover the section on all sides (figs. 10 and 11), thus avoiding an irregular and unsymmetrical accumulation of material, and the formation of fins.

It may further be of interest to point out that other sections can also be rolled—cruciform and ⊥ sections of long and thin flanges without tapering. The rolling of such ⊥ sections offers difficulties, whilst the rolling of cruciform sections of larger dimensions and parallel ribs, with sharp outer edges of nice appearance, could not be done at all before. For these kinds of sections a universal mill is very fit for the proper working of the stuff. Obviously, the value of the cruciform section is based upon the above qualities, and lies in sizes of 6 to 18 inches. The use of this form has hitherto been arrested by the difficulties of production. By ordinary rolling trains it can only be manufactured in small dimensions and with tapering ribs, useless for any structural work, whilst cruciform sections of correct form can compete in every respect with all other pillar sections. I refer in this regard to the remarks at the end of the paper, and now proceed with describing the rolling-mill system, which is shown in figs. 6 and 7 for the cruciform section in the second and last position, and in figs. 4 and 5 for the H section for the first and last pass through the universal mill. The rolls for the ⊥ sections are similar to the H ones, with the exception that the bottom roll carries a collar, corresponding with a groove of the top roll, thus dividing the H section into two parts. It has already been mentioned that the mill is chiefly intended for steel and reversing or cogging plants. The blooms are roughed down, either in a square shape for X sections, or in a rectangular one for H sections. This can be done in every cogging-mill, and thus no special previous rolls are required, which is an obvious advantage. Suppose the universal mill be annexed directly to the cogging rolls, the latter can always remain at work for general purposes, even when the universal rolls are to be changed, or have to be idle for want of orders, &c.

It will be noticed that the rolls of the H mill are arranged unsymmetrically. One of the vertical rolls (marked B′) has got projecting flanges, which, at the end of the rolling, reach over undercut faces of the horizontal rolls. The circumference of the other vertical roll is met by conical faces, which, in the tighter positions of the rolls, are overlapped by corresponding conical

faces of the horizontal rolls. In this manner the formation of permanent fins is avoided. A fin must evidently be formed at the junction of two surfaces, if the metal at that place is under a certain pressure, because it is impossible, and would be wrong, to make the surfaces a close fit; but the fin which is produced in one pass is removed in the next one, owing to the bar being turned over by half a turn. Thus the fins which are produced on the outer edges of the right-hand flange of the girder in one pass (fig. 10), are, in the next pass, effaced by being pressed into the corners of the left-hand vertical roll; whilst the fins produced at the junction on the left side are effaced by being pressed into the corners of the horizontal rolls in the next pass. The outer circumference of the vertical H rolls is not a cylindrical surface, but has a considerable camber, thus producing curved flanges in the girder. The reason for adopting this shape is, that the wear on the side-walls of the working faces of the horizontal rolls is thereby greatly diminished, owing to the shorter time the rolls remain in contact with the face of the flanges; whereas with vertical faces scraping takes place. In my arrangement of inclined flanges a kind of rolling motion is substituted. It is even preferable to adopt a much greater bending of the flanges than is shown in the illustrations, which will have the advantage of still less wear and tear of the rolls, while the rolling can begin with thinner blooms. Then only about five passes through the universal mill will be required, and the flanges are very rapidly formed, a kind of splitting of the material taking place. In the H mill, a firm grip of the inserted bar is always secured, because the driven horizontal rolls come first in contact with the bar, owing to their greater diameter; and the bite is all the better, because, at the ends of the bars, the web is, as a rule, somewhat longer than the flanges. Thus the vertical rolls begin to act after the grip has taken place. When the bar has passed through the universal mill for the last time, the flange must be squared up on a special finishing mill with four rolls.

In the rolling-mill for cruciform or star-shaped sections, the rolls are arranged symmetrically. The horizontal rolls overlap, with their conical surfaces corresponding to the surfaces of the recessed circumference of the vertical rolls. In order to make this overlapping possible without jamming, the diameter of the

vertical rolls should not be smaller than that of the horizontal ones. If the distance between the outer edges of the vertical rolls were equal to that between the corresponding edges of the horizontal ones, it is evident that the former would, by reason of their large diameter, come in contact with the bar simultaneously, or even sooner, than the horizontal rolls; and as the vertical rolls are not driven, the bar could not be pulled through the mill. In order to overcome this difficulty, the angle of the chamfer of the outer overlapping cones of the horizontal, and the corresponding undercurrent surfaces of the vertical, rolls is slightly less than 45°, and consequently the edges of the cruciform section are not quite square with the surface of the flanges, as will be seen from the annexed sketch, fig. 12, which, on an exaggerated scale, shows the section after passing in full lines, and before passing in dotted lines. The reduction of area takes place in the vertical dimension only, and it is produced entirely by the horizontal rolls, thus relieving the vertical rolls from pressure. They have almost only to keep the section in shape laterally whilst being subjected to the pressure of the horizontal rolls. As a further consequence, the formation of a fin at the corners, marked (*a*), that is, at the junction between the vertical and horizontal rolls, is entirely avoided, because the material has a rounded edge and receives no compression there. Owing to the angle of chamfer being less than 45°, the vertical dimensions of each pass are smaller than its horizontal ones; and when the bar is turned through a quarter turn ready for the next pass, its horizontal dimensions become the smaller ones, so that the bar, when being pushed in, can be firmly gripped by the horizontal rolls. Roughly speaking, the mill is set after each pass, so that the vertical rolls approach to within the same distance which existed between the horizontal rolls in the previous pass. It is a peculiarity of Sack's rolling-mill that the rolls need not be in close contact, a matter of considerable importance on account of reducing wear and tear between the rolls by friction and mill-scale, and because the exact position of the vertical rolls is independent of a close contact of the overlapping faces. Nevertheless the vertical rolls are

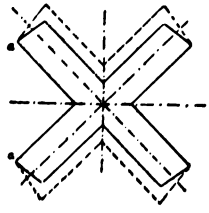


Fig. 12.

ery firmly kept in their correct place by means of the action of ne wedges of the vertical bearing-boxes against the very strong etting-rails. After the last pass, the bar is left with a slightly lisplaced section, which does not really matter much. How-ever, to smooth the section, a special finishing mill is provided, in which a complete symmetry is attained.

The finishing mill is, in its general arrangement, similar to the universal mill, and serves for all cruciform sections which may be required, because working upon the outer edges of the section, smoothing not being found necessary. The housings, both for finishing and universal mills of H and X sections, are equally so that one plant is suitable for both and general purposes. The distance between the housings of the horizontal rolls is a constant one for all sizes of the cruciform sections, and with H sections for all girders from 8 inches up to 18 inches. For larger girders one of the housings must be shifted and new rails fitted.

The bloom roughed down in the cogging-mill is brought to the universal mill. A system of feed-rollers is provided with a special tilting gear driven by hydraulic power, so that the amount of hand-labour is reduced to a minimum. This tilting gear is capable of performing half a turn for H, as well as a quarter turn for X sections, and can also handle bars of very great length. A further peculiarity of this gear is, that crooked bars are straightened at the same time that they are tilted.

This tilting gear is of general interest, because it works with great accuracy, alike with crooked and very long bars, and even with flats, &c. The inventor has exhibited a small working model, and would be pleased to give all information about it.

The cruciform section in this shape, and in such sizes as 8″ up to 16″, and even more, is a novelty, specially intended for columns and architectural purposes. From the foregoing description it is evident how easily such a section can be produced in a correct form and of all requisite dimensions; and it may safely be said that it would be applied to a vast number of structures. A new market ies before the manufacturer, which he could open up at a com-aratively small cost by annexing the mill to an existing cogging lant, using existing housings, &c. To commence producing 8″, 0″, 12″, and 14″ sections, four sets of universal rolls are quite ufficient. Each section may be kept in store in two different

thicknesses of the flanges and appropriate lengths, so that any pillar can be supplied by keeping a comparatively small stock only. With Phœnix and all other built-up columns it is scarcely possible, and still less advisable, to store them in great variety; for with such sections every pillar has its special design for fixing brackets, or foot or top plates, and a ready built-up column is less convenient on this account. Hence it may arise why the Phœnix column, so much in favour in America, has not got into common use in Europe, and architects rather prefer cast-iron columns, although it is a fact that rolled iron or steel pillars are much more trustworthy than cast-iron ones. Frequently the want of elasticity of the material is adduced in favour of cast-iron columns; but this quality may also be very fatal, as the collapse of the Tay Bridge will prove. Another danger may arise when the foundations of a column, cast in one piece to the bed-plate, gives way on one side. A very severe accident occurred in consequence of this occurrence some years ago at Frankfort-on-the-Main. The cellar of a brewery collapsed after the breakage of one column, although all the columns were strong enough for their purpose and of good material.

It is true that the thin walls of riveted wrought iron columns are open to the objections of greater elasticity and greater danger from the influence of rust and corrosion. Indeed, with Phœnix columns and those built up of ⌊⌋ sections and others, the thickness of metal is about half an inch, more or less, on the average, but in the cruciform section the flanges have a thickness of one-twelfth to one-sixteenth of the width of the whole section; that is, much more than is shown above.

Nevertheless, a comparison of sections with equal strength, computed on their relative moments of inertia, shows the relative weights of material to be as follows:—Cast-iron 120; Phœnix iron, 75; and cruciform steel section, 100. With the latter at £5, 10s. a ton, it could compete successfully with castings at £4, 12s., and with Phœnix columns at £7, 10s. As, however, the bending of vertical columns of cruciform sections does not take place for a length less than twenty-five times the width of the section, it will be seen that with a 10-inch section, the column would have to be about 21 feet in height, in order that the danger of simple crushing may be equal to that of failure by bending. For

a smaller length, the column would fail on account of crushing without bending, and because for ordinary building purposes the length is, as a rule, less than 20 feet, it will be seen that an average column would have to be estimated simply by the compressive strain, which the area can bear without reference to its moment of inertia.

In this case the advantage even of the hollow circular columns over X sections has perfectly disappeared.

In bridge-building, riveted "Phœnix" and other column sections may be, to a certain extent, of better use, however inferior they may be to the cruciform section for architectural and a good many other purposes.

The cruciform section can be kept in stock ready for sale, which is not done with riveted pillars. For the latter there is a great variety in annexing girders, brackets, bed and top plates, riveting diagonal ties and flats between the flanges, &c., a variety which is pernicious in regard to establishing those sections as a regular article of trade; whilst the cruciform section, owing to its right-angular corners, offers standard faces for brackets, &c., any bracket fitting as well for a large as for a smaller section. Thus less variety is obtainable, and practical castings for foot and top plates, brackets, &c., can also be kept in stock, so that a column could be supplied at once—a matter of considerable importance for ordinary building purposes.

How very readily the cruciform section in connection with such standard castings lends itself to architectural work may be seen from the illustrations. A complete column is to be fitted up in the simplest manner with wedges or screws, and surrounded by wood or brickwork to make it of a good architectural appearance, and to afford security against fire.

It is also a good section for telegraphic poles, or for signals, fencing, and electric lighting, &c.

The wide and untapered flanges are also very fit for riveting, and secure applicability for a vast number of other structural purposes, which will give a successful future to this kind of section.

DISCUSSION.

Mr. JEREMIAH HEAD said that it appeared to him that the value of the paper consisted largely in the principle it advocated, which was that of paying more attention to the manner of forming complicated sections. The sections of finished iron and steel now in demand were very multifarious indeed, and the way in which some of them had been produced for a long time in the older rolling-mills seemed to him rather barbarous. Let them consider what happened when an ordinary channel section went through the rolls. The pressure of the rolls on the centre web tended continuously to extend it. The side flanges were formed, however, not by side pressure, but by pressure on the centre web, squeezing the iron or steel up into corresponding recesses in the rolls. The centre web was always extended by compression; but the flanges were mainly extended by stretching. When the section was done it was not at all surprising if it was under a certain amount of stress, which probably nothing but annealing would really take out of it. It appeared to him that the author of the paper had aimed at removing that difficulty. He wanted to squeeze every part of every section equally, so as to make and finish it under similar physical conditions. That seemed to him a right principle to adopt. It was not possible, in listening to a paper like the present one, rapidily read, as it had been, to follow its details so closely as to be able to form a judgment upon them. It was as much as one could do to take in what was said, let alone any critical consideration of complicated mechanical details. He understood that the author had in his mind the production of sections in steel rather than in wrought iron. But in speaking of wrought iron the author had said that it required a very soft iron, when hot—in other words, a cindery or impure iron—in order to admit of its being squeezed satisfactorily into the deep grooves, as occasionally required. There was no doubt that that was so. He had often noticed joists which had come from Belgium, made of inferior iron, with splits in them even before they were used by the builder at all. If they had to enter into the structure of important bridges, where they would

have to be riveted, and so on, the "reediness," as it was called, would be a very great disadvantage. But as they were, to a large extent, simply put into buildings as joists, without any work to speak of on them, it did not matter so very much. The effect in the case of wrought iron, too, of the direction of rolling must always be borne in mind. A wrought-iron plate, in going through the rolls, was extended at every pass lengthways, but crossways it was not extended at all. The only way to get extension that way was by what was called "spreading and turning"—*i.e*, turning the plate round and rolling it the other way about. When it got out to a certain length it became obviously impossible to turn it; and unless it was rolled equally both ways (he was then speaking of wrought iron), the physical qualities which were so much desired—namely, tensile strength and capacity to extend—were not equally obtained; consequently they found that an iron plate was weaker and extended less across the grain than it did with the grain. That was still more so in the case of section iron—bars and strips—where all the rolling was in one direction, and exactly parallel. He thought he remembered Mr. Adamson stating, at the Paris meeting some years since, that the cross-grain strength of common bar iron was not more than 14 tons to the square inch.

Mr. ADAMSON: Bars 8 tons.

Mr. JEREMIAH HEAD said that probably in the lengthways tests those bars would stand 23 or 24 tons. That showed the extraordinary effect on wrought iron of the direction of rolling. In steel it was somewhat different, because he believed he was right in saying that the strength was nearly equal both ways, which gave that material a very great advantage. On the other hand, he questioned whether, in the case of, say, channel sections in steel, where all the web was finished under compression and the flanges under tension, such channel sections were not finished in a condition of internal stress which could only be removed by subsequent annealing. He thought that they ought to be very much obliged to Mr. Sack for bringing his paper before them, and for the attention he had paid to the matter. It was a direction in which, he had no doubt, much more could be

done. The quantity of rolls kept in merchant mills in order to satisfy the multifarious sections demanded by the market was something wonderful.

The PRESIDENT: Appalling!

Mr. JEREMIAH HEAD agreed that it was really appalling, as the President had remarked, and it tended to increase year by year. If any one was putting down a merchant mill, it was not so much a question of the cost of the mill and the engines which he had to consider, as of the extraordinary number of rolls which he must keep in stock. Then, again, there was the difficulty of the frequent changes of the rolls. If a consumer wanted a few bars of any particular section on a manufacturer's list he usually could not get them without waiting a most unconscionable length of time, because the manufacturer told him it did not pay him to change rolls except for a large order. Of course, if they could get their merchant trains to do with fewer rolls, and lighter rolls, the better generally for them, and the better also for every user of finished iron and steel.

Mr. E. A. COWPER said that he did not like one statement in the paper to go unchallenged, namely, that if a column was twenty times as long as it was in diameter, the crushing strength only had to be calculated. Mr. Eaton Hodgkinson's experiments very clearly proved that it depended partly upon whether the end of the column was flat or round, and upon its proportionate length. Speaking generally, he agreed that a short column gave way as much by crushing as by bending, but a long column always gave way by bending, more than by crushing, whether it was round at the end or flat. With regard to rolling any section, as he happened to be the first to roll large channel iron, he might say that he had no difficulty whatever in doing it when the rolls were properly turned to his order. He thought it was wrong to state that the cruciform shape was economical in point of metal for the strength of a column or a girder. The metal in the middle of a cruciform section was of little use. What they wanted was to have all the metal as far as possible accumulated on the outside or largest diameter; in other words, a tube

was a far stronger section than any cruciform form. He had tried experiments with tubes, angle irons, T irons, and other sections, and he was in favour of the tube, as being by far the most economical form of column. There might be some little advantage in a cruciform section when a column had to be protected from fire by brickwork surrounding it, and also as being more convenient for attachments. The columns of the first Exhibition building were made with four flat faces, in order to afford facilities for fixing sashes, &c. The rolling-mill of the late Mr. Richard Prosser, of Birmingham, had four rolls for rolling tubes, and answered its purpose perfectly well.

Sir HENRY BESSEMER, F.R.S., said that some thirty-two years ago he had some views in accordance with the system that had now been elaborated in a manner very superior to anything that he had done at that time, and with promise of producing better bars than it was possible to produce in the ordinary way of pinching the bar in the middle, and forcing the metal unwillingly up in the narrow groove, stretching the centre only, and allowing the other parts to be stretched as best they might, tearing itself generally in a longitudinal direction, or nearly so. On one occasion he was required to produce some very large angle iron for the support of armour-plates on the sides of a ship. An angle of 12 inches on each side was rather a difficult thing to produce in the ordinary way, but he succeeded in producing it by a method which he illustrated on the black board. For the production of these angles an ingot of mild steel was cast in an iron ingot-mould of the sectional form shown in fig. 1, and was

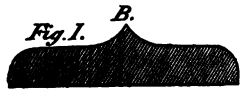


Fig. 1.



Fig. 2.

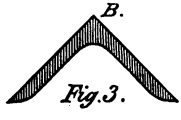


Fig. 3.

then rolled down until it assumed the proportions shown in fig. 2, after which it was formed into an angle by passing it through rollers having large V grooves, the operation in these rolls being merely one of bending the flat plate into an angle, the raised rib, B, on the plate furnishing the metal necessary to

form a sharp outer angle and a full rounded part on the inside of the angle plate, as shown in fig. 3. One of these angles was most severely tested by twisting and bending when cold, and may now be seen at the Museum in Jermyn Street. Sir Henry further referred to a system he had proposed at the same early period for the production of T girders. He was pleased to state his opinion that Mr. Sack's paper was well worth the attention of manufacturers, and a step in the right direction.

Mr. JAMES RILEY said that Mr. Jeremiah Head had made a remark to him which seemed to render it necessary that he should say one or two words. Mr. Head asked him, "How are you getting on with that mill at Newton?" Mr. Head had understood Mr. Sack to say that the mill had been erected, and was being worked at the Newton works. That was not the case. What was done was, that the little mill which they saw at the top of the stairs was brought by Mr. Sack to Newton, and was temporarily fastened down—exceedingly temporarily—at the end of one of their small bar-mills. Mr. Sack himself rolled there several small pieces of steel to the section he had described, and he was bound to say that he did it exceedingly well, and, further, that the mill did that gentleman immense credit. It showed that he had given a very great deal of thought to the matter. The result was a mill in which all the parts had been carefully thought out and completed in a most ingenious manner, and Mr. Sack had got over most of the difficulties which presented themselves. The tilting-gear, also, was one of the most ingenious things any one could wish to look upon as applied to the turning over of the beams: it was a most beautiful thing. It might be asked, those things being so, why had they not put down a mill? Every one knew that there were a great many considerations connected with a decision of that kind. He was not sure that the market was ready to hand as described by Mr. Sack, and he was not sure that the remuneration would be at all such as Mr. Sack sanguinely expected. Further, he did not think that the mill could be put down in connection with other mills in the way Mr. Sack described. He said to Mr. Sack, with much regret, that he could not recommend his directors to put down that mill. It was not convenient to do it in connection with the

ther branches of their business, and with the arrangements of he mills at their works. What Mr. Sack should do, if he was o satisfied with the market—with the demand there would be or those sections, because, as the meeting would have observed, he sections that Mr. Sack could produce were only few in number—if he was so satisfied of that, he should really get a special works specially designed for that particular business, and put down the mill in them.

The PRESIDENT said there was no statement in the paper as to the quantity of work which could be turned out in one of the mills. There was no doubt that the section could be rolled, but a very important point for the consideration of steel-makers would be the amount of work that could be turned out per turn of the sections referred to. Mr. Sack was not present, nor had he a representative, but he had great pleasure in moving that the best thanks of the meeting be conveyed to him for the paper he had furnished.

The motion was agreed to, and the meeting was adjourned.

FRIDAY, MAY 10.

The proceedings of the Institute were resumed to-day—Sir JAMES KITSON, Bart., President, again occupying the chair.

The following paper was read;—

THE APPLICATION OF THERMAL CHEMISTRY TO METALLURGICAL REACTIONS.

By ALEXANDRE POURCEL, Saltburn-by-the-Sea.

In his book on the subject, Mr. Pattison Muir defines thermal chemistry as the science that "treats of the mutual relations between chemical and thermal phenomena." "It is still in its infancy," he remarks, "and the facts amassed are not very numerous, nor sufficiently clearly interpreted, to render their application productive." Mr. Pattison Muir's opinion is slightly pessimistic, and is hardly justified, more especially in the field of organic chemistry. If thermal chemistry is still poor in results, work should be done with a view to add to their number and not to question their value.

The fundamental principles of thermal chemistry consist of a small number of theorems, of which the two principal are the following:—

1. The heat absorbed in the decomposition of a substance is exactly equal to the heat disengaged at the time of the formation of the same compound. This fact was shown by Laplace and Lavoisier as far back as 1780.

2. Every chemical change effected without the intervention of an extraneous force, tends to produce the body or system of bodies that disengages the most heat.

With the aid of these two theorems, it is possible to satisfactorily explain the reactions occurring in industrial chemistry. For this purpose numerical data are at our disposal. These data, published in Mr. Pattison Muir's elementary work and in Berthelot's "Essais de Mécanique Chimique," express the amount of calories disengaged or absorbed in the combinations of elements or compounds, in the state of gas, liquid, or solid. All these numerical data have been determined by the authorities on thermal chemistry: Dulong, Hesse, Graham, Andrew, Fabre and Silberman, Thomsen (one of the most productive writers), Troost, Hautefeuille, &c., and lastly by Berthelot, who has collated all

the papers bearing on thermal chemistry with a view to place them on record in his admirable work. The figures, which are there shown grouped in tables, give the quantities of heat calculated in ordinary, or small, calories, in proportion to the equivalents of the elements, that of hydrogen being taken as unity. The small calorie *c* is the amount of heat required to raise 1 gramme of water from 0° to 1° C. The large calorie, *C*, is a thousand times greater.

The numerical data I employ are either extracted from Berthelot's "Mécanique Chimique" or calculated from the figures supplied in his tables. The first example relates to the manufacture of ammonia-soda.

Ammonia-soda.—The two bodies that unite to form this substance are sodium chloride, NaCl, and ammonium bicarbonate, $C_2O_4NH_3.2HO$; the two new compounds being ammonium chloride, NH_3HCl, and sodium bicarbonate, $C_2O_4.NaO.HO$. The elements forming these two bodies have been supplied by the decomposition of the sodium chloride and the ammonium bicarbonate. This phenomenon of decomposition has absorbed a certain quantity of heat equal (Theorem No. 1) to that which was disengaged on the formation of these bodies.

Thus NaCl in being decomposed into Na + Cl absorbed 96·2 calories; $C_2O_4NH_3.2HO$ in being decomposed into $C_2O_4NH_3$ and 2HO absorbed 30·4 calories; total = 126·6 calories.

To this figure 126·6, there remains to be added the number of calories absorbed by the decomposition of an equivalent of water, HO, into H + O; namely, 34·5 calories, in order to supply the oxygen and hydrogen necessary for the formation of NaO and HCl that enter into the composition of the ammonium chloride and of the sodium bicarbonate. The total is then 126·6 + 34·5 = 161·1 calories. The two last-mentioned substances have, on their formation, disengaged a number of calories greater than 161·1; for if that had not been the case, they could not have been produced. The following are the details given for the *liquid* or *crystallised* compounds:—

	Calories.
$H + Cl = HCl$, disengaging	39·3
$NaO + O = NaO$, disengaging	77·6
$HCl + NH_3 = HClNH_3$, disengaging	38·5
$NaOHO + C_2O_4 = NaOHOC_2O_4$, disengaging	30·8
Total number of calories disengaged	186·2

This number is greater than the preceding one by 186·2 − 161·1 = 25·1 calories. It may be considered as the co-efficient of affinity that has determined the formation of these new compounds, for *the work of affinity is measured by the quantity of heat disengaged by chemical transformations effected during the act of combination.*

These reactions may be followed more readily if the sodium chloride in solution is considered as a chloro-salt, HCl.NaO, which on being decomposed into HCl + NaO absorbs 13·7 calories. The ammonium bicarbonate, on being split up into its elements, C_2O_4, NH_3, H_2O_2, absorbs 30·4 calories. The total amount of heat absorbed thus amounts to 13·7 + 30·4 = 44·1 calories. Ammonium chloride and sodium bicarbonate, as stated above, disengage during their formation 38·5 + 30·8 = 68·3 calories. The difference, 68·3 − 44·1 = 24·2, gives practically the same figure as that obtained above as co-efficient of affinity having determined the reaction.

The manufacture of ammonia soda gives a by-product, calcium chloride, which is not utilised because the chloride cannot be extracted on an industrial scale. The CaCl, having become anhydrous and heated in contact with silica in a current of air, gives up its chlorine. This is, however, not an economical method of utilising this by-product. Submitted to the action of a current of hot air, calcium chloride remains unaltered, for, the combination of Ca with Cl having disengaged 85 calories, the chlorine cannot be displaced from its combination with calcium by the oxygen whose co-efficient of affinity with calcium is only 66 calories. Magnesium chloride, on the other hand, gives up its chlorine on its conversion into MgO when submitted to the action of a current of hot air. The number of calories disengaged by the combination of Mg with O is practically equal to that of the calories disengaged by the decomposition of MgCl into Mg + Cl. These two figures are somewhere near 75. In the ammonia soda industry, too, lime has, for some time past, been replaced by magnesia for regenerating the ammonia in cases when there occurred a difficulty which has now been overcome and which was to obtain anhydrous magnesium chloride, that is to say, to evaporate its solution to dryness without decomposing it into MgO and HCl.

Industrial chemistry thus finds in thermal chemistry a considerable number of numerical data, at least as a help, if not as a sole guide.

The data relating to the combinations of the substances met with in organic chemistry are still more abundant, since it is more specially in researches in that branch of chemistry that attention has been directed by the chemists who have studied thermal chemistry, and notably by Berthelot. On the other hand, numerical data relating to metallurgical reactions are still very sparse. Most of them have been furnished by Thomsen, the distinguished Danish professor. To Messrs. Troost and Hautefeuille are due the careful experiments that have established the heats of chlorination, and of oxidation of boron and of silicon. Their calorimetrical investigations of the carbides, silicides, phosphides, and sulphides of iron and of manganese, published in the "Annales de chimie et de physique" more than ten years ago, present the greatest interest. The conclusions they arrived at I quote below, without entering into experimental details: *—

1. Iron carbides are formed with absorption of heat from their elements. Thus, 1·04 gramme of grey pig iron, containing 1 gramme of iron, disengages 879 calories. Of white pig iron, 1·041 gramme, containing 1 gramme of iron, disengages 896 calories. Whereas 1 gramme of iron, with traces of carbon, disengages only 827 calories.

Consequently, like all bodies formed with absorption of heat, pig irons are somewhat unstable compounds which dissociate at high temperatures. By slow cooling a pig iron abandons its carbon, disengaging the quantity of heat that it had absorbed in dissolving it. If, by an artifice that accelerates the cooling, this *heat of solution* is successfully absorbed, the carbide does not dissociate, the compound remains fixed, and white pig iron is formed. This phenomenon is produced by cooling the pig iron in a metal mould.

2. Manganese and carbon unite and disengage a quantity of heat.

* The substances, filed or pulverised immediately before the experiment, were attacked by forty times their weight of mercury-bichloride, with the addition of ten cubic centimetres of water, in the platinum muffle of Favre's calorimeter maintained at a constant temperature.

Thus, a carbide of manganese containing 5·8 per cent. of carbon disengages on chlorination 1010 calories.* The definite carbide Mn_3C, containing 6·7 per cent. of carbon, does not disengage more than 386 calories per gramme. It may therefore be considered as one of the most stable compounds met with in mineral chemistry. As such, it is very probable that this compound is formed at the high temperatures of the blast furnace, and that manganese is present in pig iron, as in steel, in the state of Mn_3C. On account of its stability it is one of the last substances to be consumed by intermolecular combustion in the Bessemer converter.

3. *Silicide of Iron.*—On attacking a silicide of iron by liquid mercury bichloride, iron chloride and silica are formed.

Thus, 1 gramme of a silicide, containing 3·5 per cent. of silicon and 0·6 per cent. of carbon, disengages 970 calories. The heat disengaged by the chlorination of the iron and the oxidation of the silicon of this compound is also equal to 970 calories; and 1 gramme of a silicide containing 14 per cent. of silicon and 0·04 per cent. of carbon disengages 1270 calories; whilst the heat disengaged by the elements taken separately is equal to 1425 calories. The difference $1425 - 1270 = 155$ calories gives the heat of formation of the silicide containing 14 per cent. of silicon. The silicides of iron are therefore not very stable compounds, and consequently their oxidation by intermolecular combustion is easily effected, and under the same conditions as if their elements existed separately in the pig iron, that is to say, with the disengagement of a quantity of heat.

4. *Silicide of Manganese.*—Unlike the preceding case, silicon and manganese give very stable compounds, which are formed with a disengagement of heat.

Thus, 1 gramme of silicide, containing 12 per cent. of silicon and 1 per cent. of carbon, disengage by chlorination 1250 calories. The elements taken separately and transformed into chloride of manganese and silica, disengage 2280 calories. Consequently the elements of this silicide of manganese, containing 12 per cent. of silicon, have lost half the heat that they would have disengaged if they had been free. It should be noted that the carbide of manganese of the definite composition Mn_3C, contain-

* Metallic manganese is stated by Thomsen to disengage 2040 calories per gramme.

ing 6·7 per cent. of carbon, is more stable than the silicide of iron containing 12 per cent. of silicon, and probably more stable than the silicide Mn_3Si, containing 14·5 per cent. of silicon. Consequently, in the intermolecular combustion of the Bessemer process, the oxidation of the silicide of manganese follows that of the silicide of iron; whilst the carbide of manganese is the last to be oxidised, after the carbide of iron and even the phosphide, in the basic converter.

5. *Phosphide of Iron.*—Phosphorus forms with iron compounds of a very stable character. In treating two phosphides of iron containing 5 per cent. and 9·5 per cent. of phosphorus respectively, Messrs. Troost and Hautefeuille obtained 790 and 488 calories per gramme. The heat disengaged by the oxidation of the phosphorus, although considerable, did not hide the loss of heat. It may therefore be concluded that phosphate of iron is formed with a large disengagement of heat, and that it consequently is a stable compound. Manganese phosphates are attacked with difficulty by liquid mercury bichloride, and this is the only certain indication available of their stability, and consequently of their formation with a large disengagement of heat.

6. *Sulphides of Iron and of Manganese.*—Thomsen has determined the heats of combination of sulphur with iron and of sulphur with manganese, the results being 12 calories in the first case, FeS, and 23 calories in the second, MnS. It has also been shown by Messrs. Troost and Hautefeuille that a sulphide of iron containing 5·4 per cent. of sulphur disengages more heat on chlorination than does the iron it contains. It is thus a compound formed with absorption of heat, and consequently it is but slightly stable. I shall now show why it cannot be eliminated from the basic converter, and why this elimination is so difficult in the basic converter. The sulphide of manganese, a more stable compound, in the presence of a basic slag, combines with it because it forms, like calcium sulphide, sulpho-salts, sulpho-silicates. I have proved that in the ferromanganese slags the sulphur combined with the manganese is about one-third of that which is in combination with calcium. $Ca + S = CaS$ disengaging 46 calories.

Before giving some example of the application of thermal-chemical data to metallurgical reactions, I must enumerate the

third theorem that is required in the calculation of combustions. It is as follows:—

In order to calculate the heat of combustion of a compound, it is merely necessary to substract its heat of formation from the heat of combustion of its elements.

Intermolecular Combustions.

In the intermolecular combustions of the Bessemer process, the oxygen is supplied by the conversion of Fe_3O_4 into FeO. Consequently each constituent of the pig iron, whether simple or compound, silicide of iron or of manganese, phosphide of iron, carbide of manganese, carbon, &c., in order to take its share of oxygen for its combustion, must supply by its oxidation a quantity of heat at least equal to the number of calories absorbed by the decomposition of the sesquioxide of iron into protoxide.

For the formation of FeO, I take 34 calories, and for that of Fe_3O_4, 44·6 calories: this figure being the mean of three thermometric results.

The difference, $44{\cdot}6 - 34 = 10{\cdot}6$ calories, gives the amount of heat absorbed by the decomposition of Fe_3O_4 into $Fe_3O_3 + O$.

Combustion of Iron Silicide.

The silicide of iron, SiFe, which, according to the experiments of Messrs. Troost and Hautefeuille, is formed without any sensible disengagement of heat, disengages, on its oxidation, a quantity of calories equal to the sum supplied by the combustion of the elements of which it is composed.

$Si + O_2$	give 109·5	calories
$Fe + O$	,, 34·0	,,
SiO_2FeO	,, 143·5	,,

From this figure, 143·5, must be subtracted the number of calories absorbed by the decomposition of the three equivalents of Fe_3O_4 that have supplied the three equivalents of oxygen necessary for the oxidation of SiFe, namely, $10{\cdot}5 \times 3 = 31{\cdot}5$ calories. In total, the formation of SiO_2FeO has supplied $143{\cdot}5 - 31{\cdot}5 = 112$ calories.

It may also be of interest to know the heat of direct combina-

tion of SiO_2 with FeO. This figure is wanting; but the following reactions give an approximation to it.

When silicate of iron at a red heat is submitted to the action of a current of hydrochloric acid gas, all the iron is eliminated in the form of volatile chloride, whilst the silica remains behind as a perfectly white deposit. The co-efficient of affinity of this reaction may be calculated in the following manner:—

$$\underset{\smile\ \smile\ \smile\ \smile}{FeO + HCl = HO + FeCl}$$
$$\underbrace{-34 \quad -22}_{-56} \quad \underbrace{+29{\cdot}5 \quad +41}_{+70{\cdot}5}$$

The algebraical sum, $70{\cdot}5 - 56 = 14{\cdot}5$ calories, gives the co-efficient of affinity. Thus, silica in uniting with the first equivalent of ferrous oxide disengages at most 14·5 calories. Now, leaving out of consideration a few exceptions that belong chiefly to the combinations of organic substances, *the heat disengaged by each equivalent of the base with a polybasic acid decreases from the first equivalent to the second, and from the second to the third.*

If 14 calories is accepted as an empirical figure for the heat of combustion of the first equivalent of FeO with SiO_2, we may adopt, by analogy with other inorganic compounds, $14 \times \frac{2}{3}$ as the heat of combustion of the second equivalent, giving $SiO_2.2FeO$, and $14 \times \frac{1}{3}$ as that of the third equivalent, $SiO_2.3FeO$. This explains why, in the presence of an indefinite amount of silica, there is a tendency for the silicate SiO_2FeO to be formed.

$$\underbrace{SiO_2.2FeO}_{-(14 + \frac{2}{3} \times 14)} + SiO_2 = \underbrace{2(SiO_2FeO)}_{+28}$$

The co-efficient of affinity is $28 - 23{\cdot}4 = 4{\cdot}6$ calories.

Combustion of Iron Phosphide.

It is generally admitted that phosphate of iron is not stable in the presence of silica, that it is decomposed into phosphoric acid and ferric oxide, and that the phosphoric acid reduced by the iron returns to the state of phosphide of iron. This theory is, however, not in agreement with the following reaction:—

Tribasic iron phosphate, submitted at a red heat to the action

of a current of hydrochloric acid gas, retains one equivalent of base. Thus, PO_5, on uniting with the first equivalent of FeO, disengages more than 14·5 calories, and forms a *compound more stable* than the corresponding silicate SiO_2.FeO. Consequently silica cannot act on the phosphate of iron so as to liberate the phosphoric acid. I adopt as the co-efficient of affinity of PO_5 with FeO the number 15 calories.

The experiments of Messrs. Troost and Hautefeuille have proved that 1 gramme of a compound of 95 per cent. of iron and 5 per cent. of phosphorus, converted into dissolved chlorides, disengages 790 calories. Now, the chlorination of 0·95 gramme of iron disengages 1700 calories, that of 0·05 gramme of phosphorus disengages 122, giving a total of 1822 calories. Consequently the heat of formation of this compound is equal to $1822 - 790 = 1032$ calories.

On applying the same calculation to the second compound submitted to chlorination by the same observers, we have a compound containing 90·5 per cent. of iron and 9·5 per cent. of phosphorus, and disengaging 480 calories, whilst the chlorination of these elements taken separately disengages 1842 calories, we obtain a figure still higher: $1842 - 480 = 1362$ calories, as the heat of formation of this phosphide of iron. That existing in pig iron, if we regard it as PFe_2* or PFe, would certainly have a very considerable heat of formation, and consequently its heat of direct combustion would be very slight. This is a valuable figure, and an exact knowledge of it would be of very great interest. Not knowing it, however, we can form an approximate idea of its value by examining the conditions of its oxidation in the basic converter. This oxidation only commences after that of the iron silicide, or manganese silicide, which takes the lion's share in these intermolecular reactions, and the basic silicate of lime is formed, which here dissolves the lime. The carbon is by that time three-quarters eliminated.

Now, carbon in forming CO disengages 12·9 calories, of which

* This phosphide of iron PFe_2 is formed, with disengagement of light, by the direct combination of iron with phosphorus. Heated to a high temperature, this phosphide gives up some of its phosphorus, and the phosphide PFe_6 appears to be formed. This contains about 15 per cent. of phosphorus. But in whatever form phosphorus exists in pig iron, whether PFe or PFe_2 or PFe_6, the conditions of its intermolecular combustion do not vary.

10·6 are absorbed by the decomposition of one equivalent of Fe_3O_4 into $Fe_3O_3 + O$. Thus, $12·9 - 10·6 = 2·3$ represents the co-efficient of affinity of this reaction. On the other hand, PFe, in order to pass to the state of PO_5FeO, must decompose 6 equivalents of Fe_3O_4, or, in other words, supply $6 \times 10·6 = 63·6$ calories.

In the presence of a basic slag containing free lime, PO_5FeO once formed is decomposed into $PO_5 + FeO$, with the disengagement of at least (-15) calories, and then gives $PO_5.3CaO$, or $PO_5.4CaO$, as found by Mr. Stead, of which the formation disengages slightly more than 81·6 calories.

As the total, there is a disengagement of $81·6 - 15 = 66·6$ calories to determine this transformation of the phosphate of iron into phosphate of lime dissolved in a basic silicate. Consequently, the oxidation of the PFe, in the basic Bessemer process, is finally determined by a disengagement of heat equal to $66·6 - 63·6 = 3$ calories.

To sum up, these two figures 2·3 and 3 are sufficiently close for us to be able to conclude that it is perfectly possible to eliminate the carbon and the phosphorus simultaneously in the presence of an alkaline base or of dissolved lime. This was proved in practice when Mr. Richards rendered lime fusible by means of fluorspar in the basic converter. In the basic or neutral open-hearth, by a similar artifice, and even in the ordinary progress of the operation, the phosphorus and carbon are simultaneously oxidised. In the acid converter, the phosphide of iron cannot be oxidised because the algebraical sum of the calories absorbed by the decomposition of the oxidising body on the one hand, and of the combustible body on the other, is negative: less than 63·6.

In intermolecular combustion there is, so to speak, a struggle amongst the combustible bodies to get hold of the oxygen of which the source is limited. Those that disengage the most heat draw upon those that disengage the least.

When, however, the oxygen is freely distributed, all the combustible bodies are supplied simultaneously in proportion to their calorific capacity. This is what occurs in the processes that give refined metal or soft iron; in the ordinary puddling furnace, and,

better still, in the mechanical puddling furnace, as well as in Sir Lowthian Bell's and Krupp's washing process.

The elimination of phosphorus is thus not in direct relation with the temperature, as has been stated, but with the mode of *oxidation* employed.*

Combustion of Iron Sulphide.

According to Messrs. Troost and Hautefeuille, iron sulphide is a compound but slightly stable. Berthelot gave 12 calories as the co-efficient of affinity of the combination $Fe + S = FeS$. Its free combustion disengages a quantity of heat calculated in the following manner:—

$$\begin{aligned} FeS + 3O &= FeO + SO_2 \\ &= 34 + 35{\cdot}8 \\ &= 69{\cdot}8 \text{ calories.} \end{aligned}$$

* I have remarked that in the basic converter the combustion of carbon is effected by a co-efficient of affinity equal to 2·3 calories, and the transformation of the phosphide of iron into phosphate of lime by a co-efficient of affinity slightly greater, it being equal to 3 calories. Consequently the phosphorus may be eliminated not only at the same time as, but even before, the carbon. This appears to be shown by the following experiment:—

In a magnesia crucible, enclosed in a second crucible of plumbago, the following mixture was melted:—

100 grammes of a pig iron, containing 17 per cent. of phosphorus and 1·25 of carbon.
200 grammes of ferric oxide, containing 62 per cent. of iron and 3·40 per cent. of water.
100 grammes of pure lime } previously melted together.
80 grammes of fluorspar }

There resulted a button of metal weighing 196 grammes, covered by a dense, well-fused, white slag. The forged metal gave the following results on analysis:—

Iron.	Carbon.	Phosphorus.	Total.
99·146	0·467	0·380	99·993

Consequently nearly all the phosphorus has been oxidised by the oxygen of the ferric oxide reduced to the metallic state, and the phosphoric acid is combined with the lime rendered liquid by the addition of fluorspar. The carbon, on the other hand, has remained almost without variation, 1·25 gramme having entered and 0·915 gramme remaining in the metal. To sum up, the oxide of iron is the dephosphorising agent, and the lime merely serves to fix the phosphoric acid.

The following equation shows the amount of chemical action brought into play for the decomposition of the phosphide of iron in the presence of a sufficient quantity of lime rendered fusible by fluorspar:—

$$5\,Fe_2O_3 + 3PFe + n\,CaO = 13Fe + 3(P_2O_5\,3\,CaO).$$

The decomposition of 5 Fe_2O_3 into Fe and O absorbs $5 \times 50 = 250$ calories. The combustion of 3P disengages $3 \times 181 = 543$ calories. The combination of $3P_2O_5$ with 9CaO disengages $3 \times 81 = 243$ calories. Lastly, the total is $543 + 243 - 250 = 536$ calories, or $\frac{536}{3} = 178{\cdot}66$ calories, that have served to decompose one equivalent of phosphide of iron—PFe—into its elements.

As the combustion is accompanied by the simultaneous vaporisation of SO_2, from this figure must be subtracted the 12 calories disengaged in the formation of sulphide of iron. The result is $69{\cdot}8 - 12 = 57{\cdot}8$ calories; but the SO_2 gas cannot be formed in a medium where the temperature almost attains that of its total dissociation. The sulphur is concentrated in the acid converter. If the sulphur is eliminated by a prolonged after-blow in the basic Bessemer process, this is effected by the decomposition of the FeS by fluid CaO. We then have:—

$$\underset{\smile}{FeS} + \underset{\smile}{CaO} = \underset{\smile}{CaS} + \underset{\smile}{FeO}$$

$$\underbrace{-12 \quad -66}_{-78} \qquad \underbrace{+46 \quad +34}_{+80.}$$

The co-efficient of affinity of this reaction is equal to $80 - 78 = 2$ calories, or in other words, it is very slight.

Conclusions.

Two main facts are presented as conclusions of this hasty investigation: the first is that silica does not decompose phosphate of iron; * the second is that the temperature plays only a subordinate part in the elimination of phosphorus.

* Silica does not decompose phosphate of iron. A mixture of 0·25 gramme of $2FeO\ PO_5$ and 0·20 gramme of silica, placed in a platinum enclosed in a second crucible of fireclay, was heated to the melting-point of iron in a Schloesing furnace. A well-melted slag was obtained in the midst of a white mass simply agglomerated. The weight of the substances remained unaltered.

But in presence of iron and silica phosphate of iron is reduced to the state of phosphide, as is shown by the following experiment. On melting in a fireclay crucible a mixture composed of

0·50 gramme of $2FeO\ PO_5$
0·20 gramme of SiO_2
3·00 grammes of pure Fe

there resulted a button of crystalline and brittle white metal weighing 2·02 grammes, accompanied by a bottle-green glassy slag weighing about 3 grammes.

The metal contained 4·63 per cent. of phosphorus, and the slag 0·32 per cent., the total being the quantity of phosphorus introduced by the 0·50 gramme of $2FeO\ PO_5$. The sum of the chemical energies that have come into play in this reaction is given by the co-efficients of affinity of iron for oxygen and of silica for iron oxide:—

$Fe + O = FeO$	developing	34 calories.
$FeO + SiO_2 = FeO\ SiO_2$	,,	14 ,,
	Total,	48 calories.

These are conclusions that *à priori* I did not seek, for they completely upset the ideas I had acquired. At the same time, I present them with all the reserve necessary in substituting a new theory for an established one that appears to have been supported by facts.

If the details of the facts submitted to your criticism contain any errors, the principles, I firmly believe, are correct.

Thermal chemistry, in its applications to metallurgy, not only may be fertile in new views of the reactions of which the theory is not firmly established—not only may this science throw light upon unexplained facts and thus lead to important improvements; but it may also serve as a guide in the investigations of the future, and leave us less at the mercy of empiricism.

But new numerical data are required. The most essential ones are still wanting. And to obtain these, we must apply to the distinguished chemists and investigators that the Iron and Steel Institute numbers amongst its members. By supplying us with these data, they will render an immense service to metallurgy, and at the same time will afford a new proof of the vitality of our Institute, to which the iron and steel industry must ascribe its greatest advances during the last twenty years.

DISCUSSION.

Mr. SNELUS, F.R.S., said he thought the paper just read was one of the most important, although perhaps one of the most technical, that had been brought before the Institute for some years, because it opened a line of study which had not yet been properly applied to the metallurgy of iron. As he had for some years past been considering the metallurgy of iron and steel from the thermo-metrical standpoint, and had lately propounded and patented a process for making steel based largely upon thermal chemistry, he should be glad to have the opportunity of explaining the principles of his new process, although it had not yet been completely carried out in practice, believing that where true theory could show beneficial and economical results, novelty of manufacture would not long bar the way to practical success. It was well known that the open-hearth steel process had for some time past been running the Bessemer process a very close race in point of cost; that they could produce open-hearth steel ingots at about the same cost at which they could produce Bessemer steel ingots; and it had occurred to him to look closely into the reasons for that circumstance. The main reason, he thought, why open-hearth steel ingots could be produced as cheaply as Bessemer ingots, was that in the Bessemer process they lost from 10 to 12 per cent., whereas in the open-hearth process as carried out, by using a certain amount of oxide of iron they gained a certain amount of metal from the oxide of iron, which covered the loss from other causes; that, in fact, if they charged 10 tons of metal into the furnace, using .3 cwt. of iron ore to a ton of metal, they recovered so much of the metal out of the ore which went into the bath, that it nearly made up for the loss due to waste in other ways. That was a very important factor in regard to the cost of the open-hearth steel process; and he had asked himself, if that was so, why should they stop short at using only 3 cwt. of iron ore to the ton? Was that the theoretical quantity which it was possible to decompose? On calculation, he found that that was not by any means the quantity of oxide of iron that

they could decompose, and that, as a matter of fact, they could add much more iron to the bath. His process of steel-making, then, was based upon the reaction between the oxygen contained in the oxide of iron and the metalloids dissolved in so-called pig iron.

The PRESIDENT said he wished to bring to the notice of Mr. Snelus the fact that they were discussing a paper on the application of thermal chemistry. Mr. Snelus would know how far his observations really touched the subject. It had been suggested by some members of the Council that he should ask Mr. Snelus whether he was really applying himself to the subject under discussion, or whether he was not rather introducing the subject of a new system of manufacture, a new process which would be more properly discussed by a paper from himself rather than in a discussion on the present paper. Without wishing to interrupt Mr. Snelus in any way, he would ask him if he was really confining himself legitimately to the discussion of the paper which had been read.

Mr. SNELUS said he did not see the advantage of using mere thermo-metrical figures without also stating what he was going to use them for. If the President preferred that his remarks upon that subject should be put into a separate paper to be read at some future meeting, he should have much pleasure in doing so, but he wished on that occasion to put himself into a proper position. It would be remembered that on a previous occasion, many years ago, he had worked out a certain process of steel-making, but he was told that he had kept it all to himself for many years. He had now just arrived at the same point in his present process, and as M. Pourcel's paper trenched so much upon the subject, he did not want to let the occasion slip, and be told afterwards, "This is all very well, but why did you not tell us about it earlier?" His remarks were strictly based upon thermo-metrical considerations of the metallurgy of iron and steel; so far, therefore, they strictly bore upon M. Pourcel's paper. He admitted, however, that they went further than that, carrying the figures to a practical application. Whether they would desire

that that practical application should be laid before them during the present discussion, or whether they wished it to stand over so that he might read a paper and explain the matter at a later meeting, he left entirely to the President and the gentlemen present to decide.

Sir LOWTHIAN BELL said that, as a past President, he felt inclined to take the same view as the President had taken with regard to the remarks of Mr. Snelus. It was quite clear that if Mr. Snelus were to do full justice to himself and to the subject he had introduced, he would be carried a long way beyond the limits of the discussion to which they ought to be confined on the present occasion, and they would occupy a great amount of time on matters outside the question that M. Pourcel's paper dealt with. It referred to a somewhat new branch of chemical science, of which they were only on the threshold; and he thought they would do well to confine themselves to the subject immediately before them instead of going into any particular application of the principles involved, in the direction of Mr. Snelus's observations. Other gentlemen might be present who might desire to follow his example, and thus they might be led into a very long discussion, and might not have time to consider the principles underlying the statements in the paper that had been read. He really thought, in the interest of Mr. Snelus himself, and of his process, that he would do well to defer the subject till some future occasion. With regard to the case which Mr. Snelus had quoted as parallel to the present, he saw many points of essential difference, but he did not then propose to enter into the question. He would simply say that he felt inclined to support the view laid down by the President.

Mr. SNELUS said he should be pleased to conform to that view, and he would confine his remarks entirely to thermo-metrical figures. He did not wish, however, to give simply a few calculations without showing the practical developments of them.

He said that the reactions upon which his thermometrical calculations depended were those which he had sketched on

the black-board.* In the bath of pig iron there were certain metalloids. Carbon, silicon, sulphur, and phosphorus were the main metalloids, and he had treated only of those. They well knew that carbon and silicon were the two chief metalloids, and the reactions which took place when carbon and silicon were brought into contact with oxide of iron might be thus represented. At a particular temperature it might be that 3 of carbon decomposed 2 of peroxide of iron, and produced 4 of metallic iron and 3 of carbonic acid. Or 3 of carbon might reduce 1 of peroxide of iron, with the result of producing 2 of metallic iron and 3 of carbonic oxide. It would be an open question which of those two reactions took place when they brought peroxide of iron and metallic iron together. In the Bessemer process, as he had shown many years ago, when air was blown through the converter, the first reaction was to produce only carbonic acid. For a long time nothing but carbonic acid came off from the converter, and his explanation of that was, that the temperature of the metallic bath at that time being only 1400°, carbonic acid was the most stable body. When the temperature was raised to the melting-point of steel, carbonic oxide was the most stable body, and then the second reaction took place, and at the end of the blow they had nothing but carbonic oxide coming off, there being no trace of carbonic acid. If they brought pig iron and oxide of iron together in a molten state, it was doubtful which of those two reactions would take place, but he thought it quite probable that the same changes would take place as in the Bessemer converter. At the lower temperature carbonic acid would be formed, and at the higher temperature carbonic oxide. In regard to silicon, that was a very simple reaction—3 atoms of silicon decomposed 2 atoms of peroxide of iron; 4 atoms of metallic iron were formed, and 3 of silica, which went into the bath, and was the main heat-giving element. In regard to phosphorus, he thought that the investigations of Mr. Stead

* The reactions are as follows :—

$$3\,C + 2\,Fe_2O_3 = 4\,Fe + 3\,CO_2$$
$$3\,C + Fe_2O_3 = 2\,Fe + 3\,CO$$
$$3\,Si + 2\,Fe_2O_3 = 4\,Fe + 3\,SiO_2$$
$$3\,P + 5\,Fe_2O_3 = 10\,Fe + 3\,PO_5$$
$$3\,S + 2\,Fe_2O_3 = 4\,Fe + 3\,SO_2$$

and others would prove that 3 parts of phosphorus decomposed 5 of peroxide of iron, producing 10 of metallic iron and 3 of phosphoric anhydride. In regard to sulphur, he thought there was no doubt that when it existed in pig iron it had the power of decomposing oxide of iron, but he believed sulphur was the last of the bodies to be acted upon. Assuming that to be so, 3 of sulphur and 2 of peroxide of iron gave 4 of metallic iron and 3 of sulphurous anhydride. In considering the thermometrical results of those reactions, he assumed the following factors:—Carbon burnt to carbonic oxide, as they knew, gave 2403 calorific units; carbonic oxide burnt to carbonic acid gave 5679 calorific units; carbon burnt to carbonic acid (the highest state of combination) gave 8080 units; iron burnt to peroxide of iron (according to the figures of Sir Lowthian Bell) gave 1582 calorific units. He believed that they did not know what was the exact calorific effect of burning iron to its peroxide, but the figures he had given were enough for all practical purposes. Silicon burnt to silica gave 7830 calorific units. In calculating the results, they required the specific heats of those various bodies. The specific heat of carbonic oxide was given as ·24; carbonic acid, ·21; oxygen, ·21; nitrogen, ·21; and molten iron, ·16. He assumed that the temperature of molten iron and oxide of iron in a bath where those reactions could be brought about was 1400° centigrade. He assumed, also, that the temperature of the bath of steel when the reactions had taken place, and the steel and the slag were molten, was roughly 2000°, which was the generally accepted figure for the temperature of steel at the end of the Bessemer process. He had already given the reactions, but in order to save time, and not to make the thing too technical and complicated, he had only calculated out the result of one of those reactions between the carbon and the peroxide of iron. He had taken the top one, but he thought both the reactions took place, and therefore the figures would be somewhat modified.

Sir LOWTHIAN BELL asked what Mr. Snelus meant by saying that both took place.

Mr. SNELUS said he meant one after the other, as in the Bessemer process.

Sir LOWTHIAN BELL: Not concurrently?

Mr. SNELUS: Not concurrently. Then he assumed the composition of the metal bath to be, in 100 parts of metal—95 iron, 3 carbon, 2 silicon. He had taken that as a very simple composition. 18 parts by weight of carbon required 160 of peroxide of iron, and gave 112 metallic iron and 68 carbonic acid. It followed that 3 of carbon would require 26·6 peroxide of iron, and would give 18·6 of iron and 11 of carbonic acid. 2 parts of silicon would decompose 7·6 peroxide of iron, and give 5·3 of metallic iron and 4·2 of silica. Therefore, the total oxide of iron which could be decomposed by 100 parts of metallic iron was the sum of those, namely, 34·2 parts; and the result would be that 23·9 parts of metallic iron would be recovered from the oxide of iron. 34·2 was the quantity of oxide of iron absorbed, and it required 1582 heat units, multiplied by 34, to decompose it. He was assuming that it took as much heat to decompose oxide of iron as would be produced in forming that oxide by burning iron to it. That was the generally accepted proposition, and it followed that it would take to decompose those 34 parts of oxide of iron 54,114 heat units. But against that they had to set off that 3 parts of carbon burnt to carbonic acid yielded 24,240 heat units; while 2 parts of silicon burnt to silica yielded 7830 heat units. They thus had a total of 39,900 heat units to set against the loss of 54,114. Therefore it was only the balance they had to provide for. He left out the question of the amount of heat carried off by the escaping gases, which was not very serious; but they should bear in mind that they must add something more to the bath in the shape of caloric or heat to bring the temperature of the bath from the melting-point of cast iron to the melting-point of steel. The bath had to be raised from 1400° to 2000°. The bath contained 100 parts of metal, plus 34·2 peroxide of iron. Multiplying that by 1400, they had the total heat units in the bath to begin with, namely, 187,880. But at the finish the bath should contain 95 parts of metal from the metal itself, plus 23·9 parts of metal from the oxide, plus the 4·2 parts of silica raised to the temperature of 2000°: therefore the bath at the end should contain 246,200 heat units. They had, therefore, to add to the bath 72,524 heat units,

as whatever was wasted by being carried off in the gases by nversion or any other loss. The theoretical quantity of heat quired was no more than that produced by the oxidation of 10 rt. of carbon to 100 parts of metal, or 2 cwt. of pure carbon to ne ton of steel. Something would have to be added for loss for ne extra amount of heat required to raise the slag that they had in ddition to the oxide of iron required to carry on the process, and o raise the lime which might be put in to form a flux. But the theoretical figures required were those that he had given. If they calculated out the thermo-metrical effect of bringing molten oxide of iron into contact with molten metal containing 3 parts of carbon, 2 of silicon, and 100 of metal, the whole of the heat required theoretically to raise the temperature of the bath and to produce the reactions was simply 2 cwt. of pure carbon perfectly burnt for a ton of steel. If they considered that fact, they would see that it underlay a very serious practical problem, and he should have great pleasure on a future occasion in conforming to the wishes of the President and Sir Lowthian Bell, and explaining how he made a practical application of those thermo-metrical results.

Mr. P. C. GILCHRIST said there were one or two points as to which he must say, though they might be correct, he did not understand them as being in accordance with the little one did know about the elimination of silicon and other elements in the manufacture of steel. M. Pourcel said on page 156 that the carbide of manganese, "on account of its stability, was one of the last substances to be consumed by inter-molecular combustion;" and he repeated this idea further on. He thought it had been generally admitted that, in the basic Bessemer converter, the manganese went rather early in the process, and that if it did not go absolutely first, it certainly went *pari passu* with carbon, possibly also with silicon; and even under the most favourable circumstances, where they had a great deal of manganese in the pig to start with, one could not retain more than perhaps $\frac{2}{10}$ per cent. at the end of the operation. It was really a debatable point —how the manganese was combined in a basic pig—whether it was a carbide or a silicide. Again, on page 157, M. Pourcel said: 'I shall now show why it (sulphur) cannot be eliminated from the

basic converter, and why this elimination is so difficult in the basic converter." This was probably a misprint for the basic open-hearth. One of these two words must be wrong. If M. Pourcel used the word "eliminate" in the sense of getting out 99 per cent., then Mr. Gilchrist agreed with him. He supposed, however, that he did not intend to give it that limited meaning. At any rate, both in the basic converter and in the basic Siemens process, they got an elimination of sulphur to the extent, under favourable conditions, of 50 per cent. But there was something with regard to the elimination of sulphur that they had never been able quite to master, namely, how it was that under some circumstances one got an elimination of 50 or 60 per cent., and in others they did not get more than 10 per cent. He believed that the small elimination took place when the slag contained 10 to 15 per cent. of silica, and the larger elimination when it contained only 5 per cent. of silica coupled with under 10 per cent. of oxide of iron.

On page 160 M. Pourcel said: "Consequently silica cannot act on the phosphate of iron so as to liberate the phosphoric acid;" and in conjunction with that he would couple also the sentence on page 163, in his conclusions, in which he said: "Two main facts are presented as the conclusions of this hasty investigation: the first is, that silica does not decompose phosphate of iron." His reason for not agreeing with these remarks was, that they knew that in the basic Siemens process silica decomposed phosphate of lime, which was a rather stronger compound than phosphate of iron. This was proved by putting back phosphorus from the slag into the metallic bath whenever silica fell into the slag, as directly it became dissolved in the bath, it had been proved over and over again that they got a precipitation of phosphorus into the bath.

He would take another case, and Mr. B. Hingley, whom he saw there, would correct him if he was wrong. It was well known that, in the puddling process, if the furnace was out of order, and they got some of the silica part of the lining into the bath, where it would be dissolved by the phosphate of iron and silicide of iron present, then the iron went back; and if that was correct, he thought it was a pretty fair proof that phosphate of iron could be decomposed by silica. Then M. Pourcel said also, on

page 161, that it was "perfectly possible to eliminate the carbon and the phosphorus simultaneously in the presence of an alkaline base or of dissolved lime. This was proved in practice, when Mr. Richards rendered lime fusible by means of fluorspar in the basic converter." In Mr. Gilchrist's opinion, the presence of the dissolved lime was necessary for the elimination that was spoken of, but was not the cause of it. The cause of the elimination of phosphorus *pari passu* with carbon was what took place in the basic Siemens process, what it was very difficult to do, and what, in fact, had never been done in the early part of the basic Bessemer blow. It was this: that in the basic Siemens process they had oxygen in the mass of the metal, and at the same moment that they presented oxygen they presented a base, viz., oxide of iron, which was really the cause of their being able to eliminate the phosphorus *pari passu* with the carbon; and, indeed, not only could one eliminate phosphorus *pari passu* with the carbon, but if the process were properly conducted they got rid of the whole of the phosphorus, when there was some carbon left. Again, the bulk of the elimination of phosphorus in the basic Bessemer process was in the after-blow, when oxygen and oxide of iron were simultaneously offered to the phosphorus. What was the difference between the after-blow and the other part of the blow? Simply this, that in the after-blow one was offering base as well as oxygen, as was shown by the copious brown smoke. If one could only offer the base at the early part of the blow, one would get an elimination of phosphorus before the carbon; but as yet no means had been discovered of successfully blowing in or introducing the base at an earlier period. Again, M. Pourcel said that the temperature played only a subordinate part in the elimination of phosphorus. There he entirely differed from M. Pourcel. One could not get a practical (*i.e.*, a commercial) elimination of phosphorus if they had not got a really good heat. It was well known that in the basic Bessemer process, for example, if the heat was bad the after-blow would be longer, and it would be very difficult indeed to reduce phosphorus down to under ·1 per cent.

Mr. BAUERMAN said that Mr. Gilchrist had so thoroughly gone into the points he was about to mention that there was not much

use in repeating them, except that he would rather accentuate the general principle, that in all matters of that kind that class of work was exceedingly useful for ultimate control, and for controlling and testing in very improbable theories. But there were so many points involved which were so very minute, that tracing any minute reactions by means of those thermo-chemical equivalents would not, he thought, lead to much unless they had, as M. Pourcel had pointed out, very much closer determinations, because in the whole of these matters there was a time factor. The utmost that they got were merely end reactions, and this was just the old molecular chemistry of equivalents giving end results. What they really wanted to know was, what happened at different times in the course of the process, and how those matters were effected by variations of one element as against another. There were also a good many assumptions in those cases. Take, for instance, the paper of M. Pourcel, who stated that in slags there was a formation of sulpho-silicates. "The sulphide of manganese formed, like calcium sulphide, sulpho-salts, sulpho-silicates." He had never been able to find out that there was such a thing as a sulpho-silicate formed in any blast-furnace slag: that was to say, sulphide of calcium, found by analysis in blast-furnace slags, existed there as sulphide of calcium; and the best proof of it was, that, if they had a slag from a charcoal furnace and a slag of the same composition from a coke furnace, they might get a crystallised silicate, some very basic silicate probably, such as gehlenite or humboldtilite. But the difference was this, that in the one case from the charcoal furnace they might get perfectly bright and clear crystals, but in the other, from a coke furnace, they would be found full of little crystals usually very symmetrically arranged with a clear nucleus, the other parts being filled up with what were actually crystals of sulphide of calcium, and they had about as much to do with the constitution of the silicate as the flint pebbles in Portland cement concrete had to do with that of the Portland cement that held them. Mr. Snelus had brought before them a very interesting table, and one which, he thought, showed them the application better than M. Pourcel's remarks did. But Mr. Snelus had not stated his own case quite rightly, because he gave the heat of

oxidation of iron to sesqui-oxide as 1582; but according to Ledebur, from Fabure and Silberman's experiments, it was much higher, namely, 1796; a fact which rather improved Mr. Snelus's position. At the same time, he did not think those very high temperatures were required. They certainly did not want 2000° to melt the very softest steel. In the last determination of Osmond (*Transformations du fer et du carbone*, p. 66), the melting-point of an extra soft steel with which his experiments were made was determined to be 1510°.

Mr. SNELUS said that molten steel always melted platinum. He did not know whether the melting-point was much above it. It must be above it somewhat.

Mr. BAUERMAN said the melting-point of silica was really not wanted, because silica formed under those conditions did not exist there as such. It would pass into combination at a very much lower temperature, because what they would get would be the heat of the combustion of the silicon, *plus* the heat of formation of the dibasic silicate, and for that no very high temperature would be required. He did not make these remarks in any captious spirit, but he wished rather to point out that in things of that sort very close reasoning would be required, if they were to do much good with them. He thought, therefore, he might call the attention of the meeting to the fact that a little more exact revision of the language of the paper before it was published would be an advantage. He thought M. Pourcel could not have used some of the expressions which were to be found in the paper. He did not know whether the paper was written in French, but in that case there were sundry expressions used which did not appear to have been quite apprehended in the translation.

Mr. JOHN PATTINSON said he had not had an opportunity yet of studying the paper, and the subject was too difficult a one to speak on without further consideration. He quite recognised the very great importance of such a study, and that it was likely to lead to very important results. For the present he did not wish to add anything further.

The PRESIDENT said that Sir Lowthian Bell had kindly under-

taken to sum up the discussion for M. Pourcel, and propose a vote of thanks to the author for his paper.

Sir LOWTHIAN BELL, F.R.S., said that it was quite possible that the paper of M. Pourcel and the translation were open to the objections urged by Mr. Bauerman, but for this he (Sir Lowthian Bell) was partly responsible, because it was owing to his pressing for the paper for this session that it had to be hurriedly prepared before going to press. The communication of M. Pourcel was intended to prove that the amount of heat produced by chemical changes was an indication of the character of the changes which took place when different substances were brought together. The lesson to be learnt from the paper might turn out a very useful one. He would ask them, therefore, not to allow this germ of a new branch of science to lie unnoticed for years before they began to take any notice of it. He thought that M. Pourcel had done well in taking up the subject, even although the factors in his calculations were open to criticism. The difficulty in such an inquiry arose from the very delicate character of the experimental research upon which the factors made use of were ascertained. In the demonstrations he had exhibited on the board, Mr. Snelus had made statements which were open to objection. For instance, he assumed the possibility that $3C + Fe_2O_3$ could be made to produce $2Fe + 3CO_2$, but that was a chemical impossibility. It would be impossible to reduce all the iron according to the formula exhibited by Mr. Snelus, because, instead of all the carbon being converted into carbon dioxide (CO_2), two-thirds escaped as carbonic oxide (CO). He proposed a vote of thanks to M. Pourcel for his interesting paper.

A vote of thanks was then passed to M. Pourcel by acclamation.

M. POURCEL, replying on the discussion of his paper, remarked that, in order to have the pleasure of discussing mineralogy, Mr. Bauerman has laid too much stress on an inversion of words (sulpho-silicides in place of silico-sulphides). It was sufficient to read the words that preceded ("like calcium sulphide") to become aware of this verbal error, and not to believe that M. Pourcel

wished to say that sulphur occurred in blast-furnace slags in the state of calcium sulphate.

With regard to the remarks made by Mr. Gilchrist, he regretted that he was not better acquainted with what had been said and written on the theory of the process that bore his name. At the Sheffield meeting in 1880, Mr. Holland gave some very interesting analyses which proved that manganese was the last substance to disappear, even after the phosphorus. With white pig iron containing 2 to 2½ per cent. of manganese, chiefly in the state of carbide, the quantity of manganese after the after-blow was always greater than that of the phosphorus—0·062 of phosphorus and 0·111 of manganese; 0·044 of phosphorus and 0·147 of manganese; and 0·081 of phosphorus and 0·194 of manganese. These figures proved that if manganese silicide burned during the operation, manganese carbide—a substance more stable—oxidised slowly, and even resisted in part the extra oxidising action of the after-blow.

Invitation to the Institute to visit Alabama.

The President, before proceeding with the next paper, called upon the Secretary to read the following letter which had been addressed to him by Major Burke:—

"Long's Hotel, Ltd., New Bond St.,
London, W., 10*th May* 1889.

"My dear Sir,—May I ask you to express to the members of the Institute my high appreciation of the great privilege I have enjoyed in being permitted to attend your sittings.

"Our Northern brethren have already assured you of the warm welcome awaiting your members in that part of the United States, and I am sure that that sentiment will be most cordially shared by all my countrymen.

"Impressed as I am by the liberality of thought and high plane of your discussions, and the bearing your researches and conclusions must have upon the great problems in industry—which, after all, must determine the supremacy of nations for the future—I venture to beg that your members will become the guests of my associate, Mr. Henry F. De Bardeleben, and myself, in a visit to the principal ore and coal sections of Alabama, at some suitable time during your stay in the United States.

"It will give us great pleasure to take you, with your families and guests, from New York, Philadelphia, Pittsburg, or, wherever your rescue from our Northern friends can be effected, by special vestibule train, through the principal ore and coal regions of the South to the new industrial city of Bessemer, Alabama, from which central position you can easily and quickly see the latest and best development in furnace-building, coal and iron conditions, improved railway facilities, and the infant effort of the South to finally achieve her industrial independence by claiming a place in the manufacture of steel.—I have the honour to be, very respectfully,

(Signed) E. A. BURKE."

The PRESIDENT said that Major Burke was present, and would perhaps like to say a few words in support of the invitation given in his letter.

Major BURKE said he could scarcely within the limits of a letter say how great was his satisfaction at having the opportunity of attending the meetings of the Institute and listening to their deliberations. The enjoyment of that honour had led to a great desire on his part, that the people who possessed the technical knowledge of iron and steel and furnace-building that he was not possessed of, but with whom he was associated, should have the opportunity of coming in touch with those who were shedding light so efficiently upon those great problems. He knew that their proposed visit to the United States was not for social pleasure. They were studying the conditions that affected science and industry throughout the world, and their American brethren believed that they had something that they could show them of interest, and they wanted to reciprocate, if they could, the liberality and generosity of treatment that he and his fellow-countrymen had found from the moment they touched the English shores. He had been a recipient of that liberality to an extreme degree, and had learnt to feel how little they knew on his side of the water, and how much they had to learn. He hoped, therefore, that their English friends would afford them the opportunity of coming in touch with an Institution which was doing so much for the elevation and progress of mankind. He

had, on the previous evening, drafted a few notes to hand to the Secretary, to be referred to if desired by the members,* knowing that the meetings were drawing to a close, and that it would not be possible for him to present to the members in detail the particulars of the desired visit. He had in his notes given a brief description of the conditions by which they were surrounded in the industrial city to which the members were invited. He was sorry that they would not be able to show their friends on the occasion of their visit an American city "in boom," as they might have done a few years ago. They had got rid of that business, and were now building on pay-rolls. The city lay between the great Warrior and Cahaba coalfields, with 8000 square miles of coal on one side, and 350 square miles on the other, with a rib of ore in the Red Mountain, where they had in the different veins an aggregate of 31½ feet of iron, the largest seam—the one upon which the principal companies were now mining—being 14 feet thick. On the other side was a rib of brown ore, and their furnaces were built in the valley on the limestone. The distance between the two coalfields was four miles. They therefore believed that they could show the Institute a place where the coal, the iron, and the limestone were in closer conjunction than at any other point in the world. Selecting that *locus*, they had two furnaces which had been going for some time, and they had added two more. They were 125-ton furnaces, from which they were getting an average of about 100 tons a day. By the time the members of the Institute arrived there, two more furnaces would be completed, or nearly completed, and one 60-ft. furnace, making seven blast furnaces, with one rolling-mill, and giving work to about 600 men. They had named the town with a purpose. It was only born two years ago, and they had a population when he left of about 4500, but he would not undertake to say what it might be by the time the members arrived there. They had two or three handsome hotels, and a newspaper which he had had the honour of establishing. They began to build the town on the 14th of April, and on the 17th of May they were cutting the stumps out of the streets. With regard to the newspaper, he was happy to say, as the proprietor, that it had never

* The notes in question will be found in the Appendix.

called upon him for a dollar for its support since the first week of its issue. They had their banks, their waterworks, &c. Altogether, he believed that they would be able to show their friends a very handsome and a very hospitable city. Four miles away were the coal-measures, and on one seam they were mining from 9 feet 4 inches to 10 feet 6 inches. A few miles above them the Woodward Company was mining upon a 6-feet bed. The Pratt vein at Birmingham was a 4-feet 4-inch vein. Near Tennessee River there was a thinner one running down to 2 feet. The Warrior coalfield was something like the shape of a ham, the lean end resting upon the Tennessee River, and the thick part opposite their own position. He would not detain the members longer by a description of what he hoped they would see. He would only say that he trusted that by the time they arrived his friends would have made progress in their effort and determination to apply the basic process to the treatment of their ores. They hoped also to have made some progress in developing the Bessemer ores which they found lying in the northern part of Georgia, and extending up to North Carolina. They had made iron last year at 8 dollars 68 cents at the Woodward furnaces. Mr Hewett had stated that he thought they could get it at from 30 to 35 shillings. By the time they arrived he thought they would be able to show iron at 7 dollars 52 cents. They coked at about 80 per cent., and he thought that the sulphur was under 1 per cent. If the members could time their visit so as to have the full trip, his friends would be exceedingly happy, and their stay at Bessemer would, he hoped, be prolonged entirely at their pleasure. With regard to Mr. Bardeleben, the gentleman with whom he was associated, it might be well for him to say a word. He had been a poor boy, who was employed by Mr. Daniel Pratt. He married Mr. Pratt's daughter against Mr. Pratt's wish, but it had turned out all right. He was now in the construction of his thirteenth furnace, and would therefore be able to afford the members the best information on the subject of furnace construction in that section. He trusted that they would favourably consider the invitation, which he now desired to repeat.

Sir LOWTHIAN BELL, F.R.S., asked to be allowed to do what he

was sure the Iron and Steel Institute would be very anxious to do —to thank their American friend for his kind and hospitable offer to receive and entertain them in Alabama. He (Sir Lowthian Bell) believed that he might claim some credit for having acted the part of a true prophet. When he visited a city in Alabama, or the few houses which were dignified by that name, it consisted of a considerable plain of a not very attractive appearance, upon which some imaginary lines were run at right angles to each other. At the corners of the squares so set out he saw a house or two. Sometimes there was one at every corner, but that was a rare occurrence. On the whole, the place had less resemblance to a city than anything he had ever seen. It was situate in an old charcoal-producing country, where in olden times there were very large forests, which supplied the ironworks with fuel; but after the discovery of the magnificent beds of coal of the district, charcoal was abandoned, and coke was used in its place. Trade, however, at the time of his visit, was so bad that no coke furnace in Alabama was in activity; but notwithstanding those very unpromising circumstances, he ventured, in a report which he had the honour of making to the British Government with regard to iron trade of the United States,* to say that in his opinion Alabama and Georgia (especially the former) were destined to be the great iron-producing States in America. Indeed, he had not seen any part of the world that could produce iron more cheaply or of better quality for ordinary purposes than those two Southern States. He forgot how many hundred thousand tons a year were being produced there at the present time, realising to the fullest extent that which he had ventured to predict.

Major BURKE said the amount of their production was nearly 1,800,000 tons a year.

Sir LOWTHIAN BELL said that that was almost as much as Cleveland produced, and when he had said that he had said everything that could be said. He had determined to go to the United States next year, but after hearing the letter that had just been read he

* "On the Iron Industry of the United States, and a Comparison of it with that of Great Britain."

should hesitate. It appeared that there would be such a contest between the Northern and Southern States as to which had to entertain the Iron and Steel Institute, and the hospitality of his friends on the other side of the Atlantic was such, that he was afraid that the contest might be attended with danger to their visitors. Nevertheless, he had great pleasure in proposing that they should give their hearty thanks to Major Burke for the good intentions contained in his very kind invitation.

Mr. JOHN ROGERSON, in seconding the motion, said that when he was in the district in 1862 General Key took possession of his portmanteau, kept it, and told him that he would not be allowed to leave the place, although he had engagements elsewhere. He was quite sure that the members would receive abundant hospitality on the occasion of their visit.

Major BURKE said that he had seen some gentlemen from Germany at the meeting; he did not know whether they were members of the Institute or not, but he ventured to hope that they would not be omitted from the invitation.

The PRESIDENT said that those gentlemen, who were members, would be included in the invitation.

Major BURKE said that there was an English superintendent at the furnaces, and a Welshman in charge of the coal-mines, and possibly by the time they arrived there might be a German over the coalfields.

The proposed vote of thanks having been carried by acclamation,

The PRESIDENT said he had heard it remarked that the English language was only properly spoken in the United States of North America. At any rate, when they went there, if they did not learn much with regard to the manufacture of iron and steel, it was very clear, from the examples that had been set them of American oratory, that they would receive some most excellent lessons on

public speaking. Mr. Hewett had already delivered an eloquent oration in giving his invitation to the members, and he thought it had been equalled by the warmth of the invitation coming from the South. He could not do better than at once accept, on behalf of the members, the invitation to visit Alabama during their projected visit to the United States.

The following paper was then read :—

ON THE THOMASSET TESTING MACHINE.

By Mr. FERD. GAUTIER, Paris.

The testing machine to which I alluded in the discussion of Mr. Adamson's paper,* at the Edinburgh meeting, is not a new one. It was exhibited in Paris eleven years ago. The *Grand prix d'honneur de mécanique* was awarded to it, and the rapidity with which its employment has been extended in France and in other countries shows that it is considered as the best type applied to the determination of quick and accurate tests.

This machine was adopted by the French navy for their dockyards, and by the French War Office for their several works. The railway companies, and almost all the iron and steel works in France, employ it exclusively.

In describing this testing machine, I will endeavour to explain the reason of the special favour that has been accorded to it.

What must be required from a testing machine? An exact measure of the strength and an easy control of the power employed.

The most simple of the testing machines is an ordinary lever, with a power not superior to 10 or 20. Such was the first testing machine of Mr. Kirkaldy, with which he has made such interesting experiments on the metallurgical products of this country. I am glad to be able to acknowledge here the importance of the results arrived at by Mr. Kirkaldy which were published by their author.

Such was also the testing machine employed by Mr. Knut Styffe, of Stockholm, whose scientific study of the pulling stress is well known.

With a single lever, if you have a small power, you must work slowly and carry numerous weights.

If the ratio between the two arms of the lever is high, you

* *Journal*, No. II., 1888, p. 31.

have a long beam subject to oscillations, and the machine must have an accurate edge.

The multiple levers which were mentioned in the paper of our past president (Mr. Adamson) have the advantage of a quicker working, and, if the edges are properly made, that fact can be made of good service, although the entire control of so complicated a machine is a difficult and tedious affair. But, speaking generally, every testing machine in which weights must be carried in order to learn the strength of a specimen is subject to *involuntary* as well as to *voluntary* errors, since you can never know if the weight added is really carried by the bar to be tested.

Hydraulic pressure was employed in testing machines in order to arrive at a quicker rate of working, and especially for the attainment of high strains, say from 10 to 100 tons. If the strength is measured by a weight rolling on a beam, it is subject to the same kind of errors which I have mentioned above. If measured by an ordinary manometer, you have the friction of the leather, which interferes with the accuracy of the figures obtained.

In order to produce this hydraulic pressure, you have generally one, two, or, better still, three pumps actuated by a special engine. This arrangement is subject to shocks, owing to the dead points of the cranks, and it is expensive. You see, therefore, that it is a difficult problem that has to be solved.

The ideal testing machine would be such that—

1st. The effort supported by the bar to be tested would be *continuous*, and without shocks.

2nd. The result should be measured exactly, without the hand of any operator.

Of course several systems of testing machines answer more or less fully to these requirements.

The *Thomasset* machine * is designed to work on this basis, and that is the reason of its employment in the French works which look seriously to the accuracy of their experiments.

Though the principle of the Thomasset machine was successfully adapted to compression, flexion, and twisting, I propose to speak specially of the *pulling stress*, for which it is mostly employed.

* Vollot & Badois, constructors, 8 Boulevard de Vaugirard, Paris.

1. Production of the Pressure.

The pressure used is hydraulic; but, to get rid of the irregularity resulting from the use of the pumps, Mr. Thomasset employs a *compressor*.

As shown in Fig. 1, the compressor is a vertical hydraulic press, whose piston is moved downwards, continuously and slowly through two fly-wheels, acted, as regularly as possible, by hand. The horizontal rotation thus obtained is turned into a vertical one by a worm-wheel and gearing, the vertical rod being screwed to the head of the ram. The water thus compressed is pushed into another hydraulic press, which gives, effectually, the pulling stress.

2. Action of the Pressure on the Bar.

The testing machine itself is made of a strong cast-iron framing, which requires no foundations, and which bears an hydraulic press, a connection with the bar to be tested, a lever of five powers, and a round plate acting on a bath of mercury, connected with a manometer.

The bar to be tested is fixed, on one side, to the ram of an hydraulic press, and on the other to the short arm of the lever.

In order to test several lengths of bar, without any special accommodation, the ram of the hydraulic cylinder into which ram the water coming from the compressor is pushed, is made of two cylindrical and concentrical parts, which are screwed to each other and which can move forwards or backwards through a fly-wheel acted on by hand. The sample being in its true position, the communication between the compressor and the hydraulic press is opened.

It is easy to see that the effect of the pressure is to act through the lever on the drum plate, covered with an india-rubber leaf, and there is *an equilibrium between the strength of the bar and the weight of a cylinder of mercury, having the diameter of the round plate and the height to which the liquid is raised in open air.*

The indication of the pressure is *self-acting*, and provided that these indications are true, you have only to read the weights

upported, and write the heights of the column of mercury, to et the result required without difficulty.

You have, as a photograph of the test, the eye following the ising of the column of mercury, and the hand measuring with allipers, or some registering apparatus, the extension of the sample. At first the column of mercury is rising regularly; it is the *eriod of elasticity*. The elongation is proportionate to the effort. Suddenly there intervenes a very short period, during which the mercury stops and goes a little down, indicating the *limit of lasticity*, as it could be easily proved in discharging the sample of the pressure, and measuring the distance between the marks. Then, the elongation proceeding more quickly than the pressure, the mercury rises slowly again, but regularly, to a *maximum*, which must be noted, and which is the *breaking strength* of the ordinary testing machines. When this maximum is reached, the striction of the bar begins, the elongation is accumulated in this part of the sample, and the mercury falls. By and by, however, as the effort supported decreases, there is no more equilibrium, and at last the point of rupture is reached. If you look at this moment at the column of mercury, you see that there is a decrease of 10, 20, and perhaps as much as 50 per cent., as compared with the maximum observed. This is, in reality, the measure of the weight supported by the area of the sample at the time of rupture. If you divide by the original section of the bar the weight corresponding to the maximum of the height of the mercury, you have the *breaking strength* in tons per square inch, or in kilogrammes per square millimetre, according to the units employed. If you divide by the area of the broken bar, the weight corresponding to the column of mercury, at the point of rupture, you have a new number, not employed in practice, but which is the breaking strength per unit of section of the broken bar.

Mr. Kirkaldy, in his interesting studies on the pulling stress, was the first to attract attention to the *contraction of area* when the point of rupture is attained. He had shown the relation between this *striction*, or local deformation at rupture, and the *percentage of elongation*, which was always considered as a proof of the mildness and the relative value of the metal. He suggested the employment of the *breaking strength per square inch of the broken area*, as a substitute for both elongation and pulling

stress at rupture. But this was a mistake, and for several reasons, which I shall proceed to enumerate.

1. What was called the *breaking weight* is only the maximum weight carried by the sample. But as soon as the striction begins, and this kind of *flowing of the metal*, which will end by the rupture, takes place, *the breaking weight is no longer carried by the bar*. In the ordinary lever-testing machines, the lever is no longer horizontal; it falls, but you cannot measure to what extent this weight is no longer carried. In the Thomasset machine the column of mercury falls, and its height is the measure of what is carried by the bar. That is a great advantage as compared with the old systems of testing machines.

2. If the breaking weight is not carried by the bar at the moment of rupture, you cannot divide this weight by the contracted area at rupture.

It is a known fact that the percentage of elongation is variable, according to the length of the bar. Thus, when you speak of a metal with so many tons per square inch of *breaking weight*, and so much per cent. of *elongation*, you must determine exactly on what length the test was made. Generally, it is 8 inches, corresponding to 200 millimetres, French measure, as employed by the French navy and the chief railway companies; but some people employ only 4 inches of length, or 100 millimetres, and there is no reason why other experiments should not take 10 inches or more.

Much trouble is caused by this want of uniformity, and it would be necessary to get rid of the consideration of length in the record of experiments, which must be the measure of the *structural value* of metals. But there was no question of doing so with the ordinary testing machines.

I would suggest that we should take the *weight supported at the time of rupture, divided by the area of the broken section*, as a substitute for the ordinary figures of both elongation per square inch and ordinary breaking weight. It is the same idea as Mr. Kirkaldy's of *breaking weight on the broken area*, but improved and adapted to the true facts shown by experiments.

The Thomasset machine, which shows the weight really carried by the sample at rupture, and any callipers which could give the diameter of the fractured area, would be the chief elements in

ıch a determination. It would be interesting to prove, by a ɜries of reliable experiments, that the length of the sample does ot interfere at all with the contracted area at rupture and the *ltimate weight* carried by the section.

Now, as our minds are accustomed to consider the breaking weight per original area, this could remain, but in that case it would be well to add the *ultimate strength*, or weight carried effectually by the broken section, and get rid of the percentage of elongation. This is exactly what the Thomasset testing machine can give accurately, and it is the only machine that can give such a record at the present time.

On the same principle, similar machines for *bending stress*, *crushing stress*, and also for *twisting*, as illustrated by the drawings given, are made. In the case of twisting, and also in that of testing the strength of bottles or of paper, thread, wire, and cloth, some simplifications have been introduced.

Returning to the pulling stress, the effect of the employment of the Thomasset machine is to alter the shape of the ordinary diagrams of strength.

I have recently tested some bars by this machine, and made the corresponding diagrams. In dotted lines I have marked how the diagram would be if another testing machine was employed which did not give an exact equilibrium between the weight carried and the strength of the bars.

I will add, finally, that the accuracy of the Thomasset testing machine can be ascertained by a special lever and weights, which show that the indications of the manometer are true.

TESTS MADE BY THE THOMASSET MACHINE.

Length = 100 Millimetres.	Area.		Limit of Elasticity.		Breaking Load.		Breaking Load in Kilos., per Square Millimetre.		Elongation.	Reduction in Area.
Description.	Original S.	After fracture s.	Total.	Per Square Mm.	Maximum P.	Minimum p.	Ordinary $\frac{P}{S}$	Ultimate $\frac{p}{s}$		$\frac{S-s}{S}$
	Mm.	Mm.	Kilos.				Kilos.	Kilos.	Per Cent.	Per Cent.
Special brass	200	118	5100	25·5	7320	7120	36·9	60	41·9	0·41
Steel A	145	47	5000	34·5	6190	4460	43·0	95	19·7	0·67
,, B	145	50	5070	34·9	6100	4800	42·0	96	20·4	0·69
,, C	145	44	5040	34·5	6050	4200	41·6	95	19·2	0·70

DISCUSSION.

Mr. DANIEL ADAMSON asked whether it was prudent to read
e paper in the absence of the author. The Institute would
sit Paris during the present year, and would no doubt have an
portunity of seeing the machine itself, as well as have the
vantage of the presence of M. Gautier to reply to the dis-
ssion. The subject would no doubt be better discussed in his
esence than in his absence, as he would have the opportunity
offering any explanations.
Before sitting down he asked to be allowed to thank the
ntleman from the Southern States of America for his invita-
n to the members to visit Alabama, because fifteen years
o he had invested a few thousands in that district. He had
w and then looked very carefully after it, but it had never
oked very profitably after him. He would promise to be one
the visitors to the United States next year, and he should
pecially like to go to the Southern States in order to look
the great mineral fields, and see their powers of producing
g iron so economically as he believed they were able to
. From what he had heard, he had no doubt there would be
very large gathering of the members of the Institute in America
xt year.

The PRESIDENT said he agreed with Mr. Adamson that there
s a disadvantage in reading the paper in M. Gautier's absence;
t they had already the promise of some very important papers
the meeting in Paris, both by Englishmen and French-
n—papers that promised to be of more importance than the
esent technical one of M. Gautier. As they had completed their
ogramme with the exception of M. Gautier's paper, he thought it
uld be wise, as they had still an excellent meeting, to complete
entirely. They had, as he had said, a number of papers of the
eatest importance promised for the Paris meeting, and it would
well if they could start with a clean sheet.

Mr. WICKSTEED said he thought the Institute was greatly

indebted to M. Gautier for his valuable paper. He had very politely brought it forward in consequence of a request made to him by Sir Lowthian Bell, when occupying the chair at the Edinburgh meeting, while another paper on a testing machine was being read by the late President, Mr. Daniel Adamson; and so M. Gautier had obligingly bought forward a description of the Thomasset machine. It was a very valuable contribution, because the records of testing machinery and of the shape of test specimens was very meagre in the Institute. More had been done in the Institution of Civil Engineers and the Institution of Mechanical Engineers than had been done by themselves, although the Iron and Steel Institute was perhaps more deeply interested in the question than any other. In the absence of M. Gautier, he thought that time might not be wasted if he were to emphasise a little the point that he endeavoured to make in drawing attention to the importance of taking the amount of the load carried by the fractured area. That point had been a good deal debated at the Institution of Civil Engineers, and it was really this, that they wanted a column of figures which would give a just comparison of results whatever might be the shape of the specimen. If, for example, they took a specimen six diameters in length, and compared it with another specimen three diameters in length, they might be exactly of the same material and exactly of the same quality, and they ought to give exactly the same results as to extension; but they would not give the same results, taken in percentage of the length of the specimen, because in the short specimen the local extension was the same as in the long specimen, but it formed a larger percentage of the whole because of its being a shorter specimen. Another discrepancy arose from the distance at which the datum points were placed from the enlarged ends of the specimen; but without a knowledge of those particulars, one experimenter in England, comparing the results with another in France, was unable to say whether the difference arose from a difference in the shape of the specimen or a difference in the quality of the material. M. Gautier was aiming at getting some expression which could not be vitiated by differences of that kind, and he had referred to Mr. Kirkaldy, who had made suggestions in the same direction with the same thing in view. They thought that the contraction of area at the point of fracture

was tolerably independent of the proportion of length to diameter, and of the shape of the specimen, and that it depended merely upon the quality of the material; they therefore attached great importance to the contraction of the area. Mr. Kirkaldy divided that contracted area into the maximum load that the specimen had carried, and he got a row of figures that were purely conventional—not figures professing to express any scientific fact regarding the metal, but just a conventional basis for the purpose of getting a row of figures that was comparable and on all fours with any other experiment. M. Gautier had pointed out the scientific fallacy of that, and had suggested that the veritable load which the fractured area had carried should be taken. The reason, no doubt, that Mr. Kirkaldy did not take that view was that it was easier to get the equipoise at the maximum of the strength of the sample than it was at the moment of fracture; because at the moment of fracture the changes in the equipoise were so rapid that it was difficult to catch with certainty the exact load that was supported at the moment of fracture; and he ventured to think that if great money interests were involved in a result, it would not command sufficient confidence if that result were given by a mercury column playing up and down a tube at considerable velocity, dropping with the reduced strength of the specimen, and, as M. Gautier described it, the eye photographing the position of the column. His own idea was that the eye would have a very hazy impression left upon it of the position of the mercury column at the moment of fracture when it was rapidly descending the tube. He thought, therefore, that it would be a dangerous thing to rely on such an observation, and he thought that that danger was exhibited by M. Gautier's own diagram. He had traced a descending line to show the decrease in load during the local extension—during the period that Mr. Adamson had called the breaking elongation. He had traced a descending line to show that, and he carried the line to a point that was lower than the point of first yielding—to a point lower than the point of elastic limit. There was a gentleman in the room who must have taken thousands of records of the behaviour of test specimens up to the point of fracture. He had been looking through his album in the room, containing 500 or 600 such records, but he could

not see a single case where the load at the moment of fracture in ordinary iron and steel had gone below the load where the first yielding took place. He therefore thought that M. Gautier's diagram was inaccurate, and if so, it showed how untrustworthy was the impression left upon the eye by the moving column of mercury in a tube, to base reports upon which were of great importance. Again, if they looked at the first of these diagrams, which was a diagram of a special piece of brass, it would be seen that there was a discrepancy—a disproportion, which he thought must be inaccurate. The piece of brass was 4 inches long; the elastic extension of that brass was set forth in the diagram as $\frac{3}{8}$ of an inch—that was, they could take a piece of brass only 4 inches long stretch it $\frac{3}{8}$ of an inch, and then let it go back again. According to his own belief, they could stretch it a good deal less than $\frac{1}{100}$ of an inch—about $\frac{1}{1000}$ of an inch within its elastic limit. It would have to be gutta-percha or cork to stretch $\frac{3}{8}$ of an inch and go back again; yet upon the diagram there was a stretch of 9 millimetres, which was equivalent to $\frac{3}{8}$ of an inch. He was not confusing the enlarged horizontal scale, but there were figures given of 9 millimetres within the elastic limit. The diagrams were exceedingly rough. Perhaps they might take them simply as illustrations of what M. Gautier wished to set forth, and not as responsible diagrams giving accurate results. But while bearing in mind the caution given by the President, he thought he might make a remark upon one sentence in the paper. The author had stated that he wished to know "the ultimate strength or weight carried effectually by the broken section, and get rid of the percentage of elongation." "This," he said, "is exactly what the Thomasset testing machine can give accurately, and it is the only machine that can give such a record at the present time." Six or seven years ago, Mr. Edward Richards, of the Barrow Steel Works, read a paper before the Institute on the "Physical Properties of Mild Steel," and he plotted diagrams with beautiful accuracy. He had set forth very clearly the reduced load that the piece carried at the moment of fracture. He plotted a line to show what the stress was upon that reduced area, and he called it the line of cohesive force of the material, which, he thought, well expressed what was meant. It was not the load-line, but the line showing the cohesive force of the particles of

the material. Again, in view of that statement, put forward, he thought, in error by M. Gautier, he would ask the members to look at the diagrams in the paper, and then to look at *this*, viz., the diagram shown in plate 17. It would be seen that in that diagram they had the same salient characteristics as in those of M. Gautier, namely, a sudden yielding-point at the limit of elasticity; they then had a rising curve to the maximum load, and then a descending line during the period of breaking elongation, like the descending line of M. Gautier's—not like the dotted line which M. Gautier had put in, representing what other machines would give. But that diagram (plate 17) was not one of M. Gautier's diagrams; it was a diagram hung upon that wall three years ago, and was made in a well-known English machine. It showed all that M. Gautier had contended for—the falling load before the moment of fracture; but it did a great deal more, because it was recorded by the specimen itself and by the machine itself. It did not depend upon observations, photographed by the eye, of a column of mercury that rose up and down, but it was autographically recorded in black and white upon the paper by a style. The point of what M. Gautier had expressed—the point of reckoning the load upon the reduced section—had also been worked out. The dotted line exhibited on the diagram was the line of what Mr. Richards had called cohesive force. That dotted line was a line plotted to show what the loads per inch would be if they were reckoned on the reduced area. The whole way along the line the area was reducing as the piece extended, and the whole way along, therefore, the load, if reckoned on the original area, was lower than the load if reckoned on the reduced area. The dotted line showed the stress on the reduced area all the way up, and in the end the reduced area had a stress of 40 tons to the inch. The specimen was an ordinary piece of Yorkshire iron; and Yorkshire iron which was reputed to carry 24 tons to the inch, really carried, in its cohesive force reckoned on the reduced area, 40 tons to the inch. This point was not therefore one with which makers of testing machines or makers of steel in England were previously unacquainted. Still, engineers had not largely adopted the suggestion that had been made, and something valuable might arise if people's thoughts were turned to some means by which an expression could be obtained that

would give a comparison on all fours, between specimens of different proportions. If the adoption of an expression of cohesive force was to be the solution of the difficulty, they had before them a diagram giving that solution, not made for that occasion, but exhibited in that room three years ago. There were some specimens on the table. One was a specimen of the best Yorkshire iron, pulled with about 130 tons force, and the local reduction of area could be seen. Another was a specimen that had been twisted 3 inches in diameter. Another was a specimen that had been crushed with 256 tons pressure. He showed a photograph of the machine in which these pieces were broken, and also the diagrams, autographically recorded, showing the load at the moment of fracture. Those tests, made by his machine, showed that there was no necessity for employing a diaphragm or a rising column of mercury, seeing that it was a machine fitted with an autographic recorder, and was made according to Admiralty instructions, in which the dead weight of 1 lb. in the scale-pan balanced the exact pull of 1 ton on the specimen. All the fulcrum distances were to standard measurements, and all the weights to imperial standards.

Mr. E. A. COWPER said he had nothing new to say on the subject; but having as an apprentice had to do with a mercury arrangement for the late Captain Ericson, very like what is called in old books the "Hydrostatic Bellows," he might say a word or two on the matter. Ericson had a column of mercury exactly on the same principle as that shown in the paper. He quite agreed with what had fallen from Mr. Wicksteed with reference to the diagrams now obtained by his self-registering instruments being extremely accurate. There were also the instruments of Professor Kennedy, Professor Unwin, and other gentlemen that did the same thing, and he felt bound to say that he had never seen a self-drawn diagram like any one of the diagrams in the paper, and he had no hesitation in saying that in his opinion they were wrong. When a diagram was drawn by the *instrument itself*, the character of the curve was accurately given, as the *machine* registered the pressure as the extension took place up to actual breaking; whereas the personal element came in when a person had to

watch the mercury moving in the tube, and had to keep making notes of its height all the time. He did not think that during the short time of sudden elongation and breaking a curve could be *accurately* recorded by a person making notes.

Mr. BENJAMIN WALKER (Leeds) said the machine under discussion was, in the main, a good, sensible machine. The principle of recording the force by a diaphragm was a useful one. In his opinion, however, it was no better than the lever, and the author himself appeared to have a feeling that the lever, at any rate, was very reliable, because in his very last sentence he referred to the use of a special lever and weight to test the indications of the manometer. Forty years ago he had himself made a series of experiments with the diaphragm for the express purpose of getting an apparatus that would record force without friction; but after years of experience he came to the conclusion that that was not the best way. A well-constructed lever machine was less complicated than the machine described in the paper, and was less liable to get out of order. He had made testing machines which had been at work for thirty or forty years, and which were practically as good now as the first day that they were put to work.

Mr. GOODMAN said that, as he had been referred to by Mr. Wicksteed, he might perhaps be permitted to make one or two remarks.

Mr. WICKSTEED said that the speaker was the gentleman to whom he had alluded as having made some thousands of experiments in which the whole history of the specimens was recorded.

Mr. GOODMAN said that the author had referred (page 185) to the oscillations that must necessarily take place with a machine having a very great leverage; but he appeared to forget that in using a diaphragm with a column of mercury he was also liable to oscillations. With the small machines of Messrs. Bailey of Manchester for testing wire, the column of mercury vibrated a

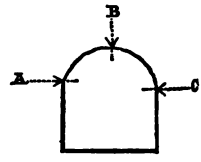
great deal, unless they were very careful in putting on the load. Without further space, a jar was liable to occur through the pumps of the testing machines. That could easily be got over, especially in London, Hull, and several other places, where they had hydraulic power laid on, by using hydraulic mains direct on to the pulling cylinder of the machine. That was first done at Owens' College, and it had been recently adopted for machines with which a great many experiments had been made for getting the higher pressures. They only had 700 lbs. per square inch on the mains in London, but they used an intensifier which intensified the pressure to 3000 lbs. per square inch, so that they could get the load very steadily, and much better than with the screw or ordinary pumps. The author referred (page 186) to shackles for testing the specimens. It was very important with a commercial testing machine that they should be able to put in bars practically of any length, varying from 2 or 3 to 12 or 14, or even 20 inches. That, however, he believed, could not be done with the Thomasset testing machine. The height of the column of mercury, he presumed from the diagrams given, was about 5 feet. That appeared to him to be too small for accurate tests up to 50 tons. With Mr. Adamson's machine a different weight was used for large and small specimens, and hence he was able to get a much longer space for each ton on the machine, so that much greater accuracy could be obtained with that system of measurement than with a column of mercury only 5 feet high. M. Gautier had also referred to getting what Mr. Wicksteed had alluded to—the ultimate stress on the ultimate area. That could easily be done on any testing machine of which he had seen the drawing. It was simply a question of working it slowly. By that means the last point on the diagram could be got as easily as any other. M. Gautier might say, "You work extremely slowly." No doubt; but he would have to work equally slowly with his machines, and even more slowly. Of course, with a machine using a lever and balance-weight, the ultimate load on the specimen was recorded by the position of the weight when the specimen broke, whereas with a mercury column they had to watch it carefully to get at the exact moment the specimen broke. To show the maximum height reached by the mercury, it would be

a great improvement to have a similar arrangement to that used for showing the maximum and minimum temperature in thermometers. The last point would, of course, have to be separately determined. Professor Barr had used an entirely new method for finding that point on the diaphragm. Underneath the end of the steelyard stock he used a separate spring, and after the maximum load had been passed and the curve began to bend down, the pressure gradually came on the spring at the bottom of the stock. That brought a pencil on the autographic diaphragm apparatus, and so automatically recorded it from the pressure on the stock. Then the length of the specimen was referred to. That was a great drawback. Every one knew that the extensions given on 10 inches were not comparable with those on 5 inches or any other length. That could be in some measure overcome by a method that they always adopted of having every specimen marked out in inches, and by having extensions of 2 inches the results were perfectly comparable. At page 189 the author said, "It would be interesting to prove, by a series of reliable experiments, that the length of the sample does not interfere at all with the contracted area at rupture and the ultimate weight carried by this section." In a paper by Mr. Hackney, in the Proceedings of the Institution of Civil Engineers (1883–84), the results were given of a number of tests made with test-pieces of different lengths and different ratios of length to diameter, and they showed that the length enormously altered the contraction of area; so much so that, with the same material, results were given of contraction of area varying from 4·4 to 52·5 per cent., due entirely to the different proportions of the specimen, the load at the same time being 65,000 to 75,000 lbs. per square inch; showing that the proportions of the specimen enormously affected the results of the test.

The PRESIDENT said the last speaker had stated that the application of force by the hydraulic cylinder was first made at Owens' College. He (the President) did not know the date when it was applied there, but he might say that the testing machine at his own works (Monkbridge Ironworks) was a double lever testing machine, and had the force applied through a hydraulic cylinder. That machine was at work nearly twenty years ago.

Mr. GOODMAN said he was referring to power from public hydraulic mains.

Mr. ADAMSON said he still thought it was a misfortune that M. Gautier was not present, because he felt persuaded that he would have been able to show that some of the results which had been questioned were accurate. He would illustrate it by the diagram referred to by Mr. Wicksteed. A material that would carry 60 tons per square inch of section, would break down with maximum load abruptly, without showing any breaking elongation, unlike a more ductile and weaker material, as illustrated by one of the figures in M. Gautier's paper, where permanent set was shown to commence at the point marked A, and the maximum load at the letter B, as in the case of a hard, strong metal, when rupture took place without warning. But with a weaker and more ductile material, less and less load was carried, and as the force diminished the action was illustrated by the above figure from B to C. He had tested some exceedingly pure iron that took a permanent set at 9½ tons: it carried 19 tons as a maximum load, and it broke down ultimately with about 9½ tons; and it would make the diagram go down to exactly the same line where the permanent set took place.



Mr. WICKSTEED: His goes lower.

Mr. ADAMSON: Then he must have had a more ductile material than he (Mr. Adamson) had. The fact was that the descending curve depended upon the class of material. It proved M. Gautier's figure, that he had a specimen that gave the exact record stated in the paper. There were many points in the paper that could be contested; but he hoped that they would have the opportunity of seeing the machine itself when they went to Paris, and of correcting some of their impressions. He thought that the mercury column was not a bad thing, after all, inasmuch as it was used for testing, but only for testing the same as in the Bailey machine, and then with only 4 or 5 powers. Those 4 or 5 powers compelled the lever to pump up and down more rapidly. But if

hey had a power of 150,000 times, then the load would only nove 150,000th of an inch, thereby laying hold of disturbing nfluences instantaneously, and the rise and fall of the mercury :hecked its action so quickly, that not only could they follow it with the eye, but they would get an exceedingly accurate reading of the result. M. Gautier had brought before them the fact that the ultimate area of fracture should have more consideration than it had received. Practically he liked the old method of reading off the ultimate strength of the broken section according to the original area. For that purpose, in testing any specimen, say an inch in area, they first of all sought out its first atomic disturbance, and then they went on to register its maximum load. The value of the breaking elongation to a practical man was this: he wanted to know, when using a certain character of material, how far he could continue his original load upon the specimen without breaking down through any accident by its full elongation; and if it carried half as much more than the original load that ought to produce permanent set, he was satisfied that there was no risk of the structure coming to destruction with a fairly good working load upon it. Even after the greatest load had been carried, there was considerable protection in an apparatus not breaking down with anything like an ordinary load of, say, one-fourth or one-fifth of its breaking elongation. To the practical user it was of considerable importance to have that record. Now, was it always injurious to have a little vibration, even during the period of testing? To his mind it was not an undesirable thing, because in actual practice a piece of metal never came to grief unless it was under some vibration or some very great distress; and if the machine nearly registered an applied load as it was found in practice, it approximated most closely to the condition of practical application. Therefore the vibration of a column of mercury might not be so great an evil as some would suppose. With regard to the water column, to which reference had been made, he had largely used it under an American patent for governing steam-engines, in which two small pumps were running at high speed; the water column affecting the action of the regulating valves so as to keep the machinery in a very uniform motion. In some applications, where the valve to be actuated required very great

force, the water column was a very fine method of controlling such a variable power. He begged to move a vote of thanks to M. Gautier for his paper. Probably at a future period the President might invite him to communicate his views in writing, in order that they might be included in the "Proceedings" of the Institute.

The motion was unanimously agreed to.

The PRESIDENT said that the proceedings of a most interesting meeting were now concluded. He had to announce that the meeting in Paris would commence on the 24th of September, and he hoped to see a large number of members present.

He now begged to move:—"That the best thanks of the Iron and Steel Institute be and are hereby tendered to the President, Council, and Secretary of the Institution of Civil Engineers, for the free use of their rooms, and for the facilities otherwise accorded for the present meeting."

The motion was duly seconded from the body of the meeting, and adopted by acclamation.

Mr. JAMES RILEY said he had much pleasure in proposing "That the best thanks of the Iron and Steel Institute, in public meeting assembled, be and are hereby tendered to the President for his admirable conduct in the chair." It needed no words from him to induce the meeting to pass the resolution heartily. It would ill become him to say anything in praise of the President's conduct, which had been such as they had expected it would be when he was elected to that honourable position. There was one thing, however, to which he might refer—the admirable address with which the President had opened the proceedings. Every one to whom he had spoken on the subject had expressed the opinion that it was one of the best addresses that had ever been delivered from that chair—an address full of lessons for them all in their various branches and departments of labour.

Mr. CARBUTT said he had pleasure in seconding the motion.

He had listened with great satisfaction to the President's address. No man could fill the office better than Sir James Kitson. He had followed Sir James's career until he became the head of two of the largest manufactures of their kind—the one making locomotives, blowing-engines, and iron and steel works machinery; the other (the Monkbridge Ironworks) producing steel and iron. The control which he had obtained over those works—managing them to the advantage of those whom he employed, as well as of himself—showed that he was the right man in the right place, and that he would be able to preside over their Institute with advantage. He had therefore great pleasure in asking the members to pass the resolution by acclamation.

The resolution was passed by acclamation, and having been duly acknowledged, the proceedings concluded.

II.

)TES BY MAJOR BURKE ON THE NEW IRON REGION OF ALABAMA (*vide* p. 179 *ante*).

In Pennsylvania the ore, I believe, is mined at great depths. The ins are 3 and 4 feet, and both coal and iron have to be hauled long stances. Ore costs say $4 to $6 at the furnace; coke $2.50 to $4; nestone $1 to $2.50; the pig costing $13 to $15 per ton.

In Alabama we have a coal supply of say 9000 square miles. The 'arrior field, 8660 square miles, has say 45,000,000 tons. The Cahaba ld is smaller, say 400 square miles, but affords excellent coking and eaming coal. It is four miles from the edge of the Warrior coal-field the edge of the Cahaba field, and between them is found rock moun- in with its brown ores, and red mountain with its red ores, showing eins measuring many feet of iron ore. The valley between these ountains, on which the furnaces stand, are beds of limestone giving s the coal, iron, and limestone closer together than at any other point n the world, so far as we have been advised.

The output of Alabama in 1874 was 49,000 tons; in 1887 it was ,000,000 tons, and this year it will be about 4,500,000 tons.

The Warrior coal-field is very much in the shape of a ham, the an end resting on the Tennessee River, near Chattanooga, where the easures are, say about 2 feet thick. At Birmingham the Pratt seam easures 4 feet 4 inches, with a 2-inch parting of slate.

The Woodward vein, lower down, measures 6 feet, with thin partings.

The Blue Creek seams, which supply the town of Bessemer, are few miles lower down, and measure 9 feet 4 inches to 10 feet 6 ches, with 2 or 3 half-inch partings.

Slopes Nos. 1, 2, 3, 6, and 7 are about the same as No. 4.

Slope No. 5 dips at an angle of 13 degrees at 1300 feet, reaches level of say 300 feet below the surface, and from there ascends on out the same angle of depth; it is 9 feet 4 inches thick, and the tput is 600 tons daily.

Slope No. 4 dips at an angle of 30 degrees; it is a 10-foot 6-inch m, with an output of 600 tons.

Our output is now 1800 tons, which we hope to increase by July to 500 tons daily.

In addition we have the Henry-Ellen mine in the Cahaba field, with 0 openings, producing 600 tons daily.

It is estimated that the Warrior basin will supply 10,000 tons daily for 300 years.

Coal is mined at Blue Creek and put into cars for 40 cents per ton; sold to the rolling mills at $1 dollar per ton, and to general customers at $1.10 per ton.

We have 350 coke ovens going, and 450 more building.

An analysis of our coke made some time since shows:—

	Per cent.
Water	·3
Volatile matter	·9
Fixed carbon	87·199
Sulphur	·681
Ash	10·92

From one of our new seams I believe it is now claimed that we get 92 per cent. fixed carbon, and under 1 per cent. sulphur.

The red mountain ore, half a mile from the furnace, crops up high above the valley, showing grey vein, iron 7 feet, sandstone 6 feet; Ida vein, iron 6 feet, sandstone 8 feet; Big seam, iron 14 feet, sandstone 10 feet; Irondale vein, iron 4½ feet; total, 31½ feet of iron. The dip is about 45 degrees.

The Sloss Company are mining on a 14-foot vein.

The Morris or Reading Company on a 22-foot vein.

The Smith's Company on an 18 to 22 feet vein.

The Woodward Company on a 12 to 14 feet vein.

With favourable appliances ore is put on to cars at 25 cents per ton. The average cost of the district is, however, about 50 cents.

The ore is sold and delivered to customers in the district at $1.10 per ton, which includes freight, royalties, and profits. Much of this ore is mined 100 feet above the level of the valley, and could be run by gravitation to the furnaces.

Within three miles of Bessemer, four-fifths of the iron ore output of Alabama is produced from seven of the largest mines in the South. The ore runs from 45 to 56 per cent. of iron, and we have just secured a railroad connection to better brown ores in a valley above, running from 58 to 62 per cent. of iron, and giving us an excellent mixture.

The furnaces are set on foundations of limestone, which is delivered by contract at 60 cents per ton; it is said to contain 96 to 98 per cent.

The Woodward Company, on the upper side of Bessemer, own and operate their railway; it is two miles from the furnace to 14 feet of ore; two miles to 6 feet of coal; and their limestone costs 60 cents.

The cost of the Woodward Company's pig last year was, I believe, $8.68, including interest on capital, and some extra expenses due to a fault in one of their coal openings. They have two furnaces, 17 by 75, from which they average about 110 tons each.

The de Bardeleben Coal and Iron Company have two furnaces in operation, 17 by 75, making a high grade of iron, with a steady output of 110 tons daily. We have grumbled a little during the recent low prices, but have found a steady sale in Pittsburgh, Philadelphia, and other points, for all that we could make.

The Bessemer Iron and Steel Company are rapidly finishing two furnaces, 17 by 75, which will embrace all the modern improvements, and the best experience of Mr. Henry F. de Bardeleben, who is now supervising the works on the thirteenth blast furnace he will have erected in the Alabama district. The construction of the furnaces has been carried out by Mr. Witherow.

The Little Belle Iron and Steel Company is also rapidly finishing a 60-ton furnace, which it was intended to devote to car-wheels and so forth, until we get ready to go into steel. We can therefore show you furnaces of a nominal capacity of 810 tons, but actually producing 720 tons per week.

The competition for the traffic has brought us seven lines of railway, connected by belt lines, and we no longer have to make expensive track extensions and pay high rates of freight, but find the roads quite willing to extend their branches along the outcrop of the coal and iron, and to haul our freight at a nominal profit.

I was informed by the superintendent of the L. & N. Railroad that the tonnage traffic of their line, below and above Bessemer, for a distance of 27 miles, was greater than the entire tonnage hauled over the Montgomery and Orleans division, of about 300 miles in extent.

I listened with great pleasure to the statement made before the Institute by my fellow-countrymen, the Hon. Abram S. Hewitt (who never loses an opportunity to say a kind and helpful word for the South), giving the result of his recent observations at Bessemer and vicinity, where he said the pig could be made at from 30 to 35 shillings per ton, and predicting for this section a most hopeful future.

Under date of March 15, 1889, in the *Manufacturer's Record*, Mr. Andrew Carnegie writes:—

"DEAR SIR,—I take pleasure in complying with your request to give my views upon the manufacturing future of the South, which I have seen during my recent visit. The first feature which impressed

me was the general excellence of the plant. The modern blast furnace is the product of evolution. The pioneers in the business have had to build and rebuild these. Our Southern brethren have reaped the advantage, and have become possessed all at once of the modern type. This remark applies also to the machinery in the mines, and modes of opening, handling facilities, and so forth. All is of the latest pattern.

"*Secondly*, the character of the coal, ore, and limestone, and the position as to mining, are all better than I had thought previous to my visit.

"*Thirdly*, ten dollars per ton for foundry iron is a liberal estimate of cost, with good management, and for a series of years some of the best located and best managed furnaces may be able to do even better than this figure; but as far as I could see, the average cost of the district must be in the neighbourhood of ten dollars, everything counting. The ability to manufacture at this price must give the Southern manufacturers a large market for their pig. When the next stage comes, and they seek to manufacture the pig into more advanced forms, I believe it will be done by converting pig into steel by means of the Bessemer and open-hearth basic processes, and I advised our Southern friends, when there, to make some experiments looking to this desirable end. As was to have been expected, speculation has entered more or less into this Southern field. Some ill-advised enterprises have been undertaken, and considerable reaction may take place; but this is only the froth upon a wave of solid wealth, and legitimate manufacturing, prudently carried on in the Alabama and other districts, will meet its due reward.

"Generally speaking, I have a much more favourable opinion of the conditions for iron and steel manufacturing in and around Birmingham than I had before my visit. Still, it is always to be remembered that success is largely dependent upon management; poor management in the South, as in any other place in the world, will ruin the best enterprise.—Very truly yours,

"ANDREW CARNEGIE.

"*P.S.*—My address before the Franklin Institute of Philadelphia on 18th contained a very encouraging reference to the South, which I regard as Pennsylvania's most formidable enemy in the future."

By the time the Iron and Steel Institute honours us with a visit, owing to our increased improvements and facilities, I think we can show you about the following result:—

Estimated Cost of Producing Pig Iron in Alabama.

	Dollars.
Ore, say 2 tons	1·10
Lime, ½ ton	·30
Coke, 1½ tons	3·37
Labour	1·50
Incidentals and repairs	·75
Interest on capital	·50
Total cost of pig	7·52

ıows that Mr. Hewitt's estimate is about correct.

› succeed in our efforts to harness the heat and gases of the coke apply these to the generation of electrical power, and utilise wer for blowing, hoisting, and tramming; and should we get ıe of interest lowered by the judicious combination of British with our natural advantages and improved facilities, we ought, application of the Bessemer and open-hearth basic processes, to ›l rails at about $18 per ton.

ıe South 20,000 miles of railway was built from 1879 to 1889, ere was expended $700,000,000 in renewals. Forty-five per all the old lines in the South are still in iron rails. We shall e with our Northern neighbours for a share of the business in ı territory at least. We are now rolling merchantable iron, and ıon to add horse-shoes, nuts, bolts, and spikes.

pig iron output of the South was in 1880, 397,301 tons, and it will be about 1,800,000 tons. The coal output in 1880 was 71 tons, and in 1887 it was 16,476,785 tons.

industrial progress of the South is not confined to the pro- of iron and coal, as within three years there has been inaugurated ew enterprises, with a capital of $168,000,000, and in cotton ve have increased from $21,000,000 in 1880, to $50,000,000 in

OBITUARY.

Dr. JOHN PERCY, who died at his residence, Gloucester Crescent, Paddington, on the 19th June last, was born at Nottingham on the 23rd March 1817. He received his early school education in that town, and afterwards went through a course of three years training at the University of Edinburgh, where he graduated M.D. in 1839. Subsequently he proceeded to Paris, and took up further academic studies, which brought him into contact with some of the leading chemists of his day. This developed a taste for chemical research, in which he was afterwards destined to acquire so high a reputation. Having completed his academical career at Paris, he travelled for a time, and on returning to England began to practise as a medical man at Birmingham. Here he acted for some years as physician to the Queen's Hospital, and his investigations in physiology and pathology won for him considerable medical fame.

Dr. Percy, however, did not care to follow out a medical career, and concurrently with his professional studies and practice, he conducted researches in mineralogy and metallurgy, and especially into the constitution of crystallised slags, having the co-operation in these researches of the late Mr. David Forbes (formerly Foreign Secretary to the Iron and Steel Institute) and Professor W. H. Miller. Among the studies which these gentlemen took up, the more prominent were the alloys of copper with manganese and nickel, the effect of phosphorus on copper, and the composition and qualities of coal.

In 1851 the Royal School of Mines was established, and Percy accepted an invitation to become lecturer on metallurgy and metallurgist to the museum. He continued to hold this position for nearly thirty years, and only resigned in 1879, when the Government of the day resolved upon moving the metallurgical laboratory to South Kensington. Dr. Percy felt very strongly that this removal was a mistake, and even went so far as to offer to provide certain facilities, which were required

o make the Royal School of Mines more complete, at his own expense, f the school was retained in Jermyn Street. He wrote, at the same ime, a pamphlet on the subject, which was published in some of the newspapers, and widely circulated, in which his reasons for relinquishing his position, and his arguments for the retention of the School of Mines at Jermyn Street, were fully set forth. Besides his professional position, at the Royal School of Mines, Percy was lecturer on metallurgy to the advanced class of the Royal Artillery (now the Artillery College) from its foundation, in which capacity he was accustomed to make excursions into the country with his pupils in order to examine different works. Another important position which he filled for many years was that of superintendent of the ventilation to the Houses of Parliament, and the requirements of this position compelled him to be in attendance at Westminster every afternoon during the session, where, having a considerable amount of time on his hands, he was accustomed to receive and entertain his more select friends.

Between 1861 and 1880 Dr. Percy was engaged in producing his well-known metallurgical works, which embraced, in addition to his admirable and unique work on Iron and Steel, treatises on all the other principal metals, as well as fuel. He also took up the rarer metals, including nickel, bismuth, antimony, &c., but his labours in relation to these were unfinished at the time of his death. Some of the volumes on metallurgy went through several editions, and all of them were translated into French and German. He had intended, for many years, to issue a new edition of his "Iron and Steel," and had prepared very elaborate notes, and had stored up an immense amount of current information, with a view to this end. But of late years his energy did not seem to be equal to the herculean labour of carrying out his long-cherished desire, and the new edition has consequently never been published. For this reason the monumental work on Iron and Steel which Dr. Percy published as far back as 1861 remains the great text-book on the subject of this branch of metallurgy, and having long been out of print, copies are most difficult to procure.

In all Dr. Percy's labours there was involved a large amount of original investigation, a great deal of which was carried on in his private laboratory in Jermyn Street. In this laboratory he undertook a systematic investigation of the iron ores of Great Britain, suggested and assisted by the late Mr. S. H. Blackwell, as far back as 1851. The results of these labours, continued over several years, are embodied in his well-known treatise on Iron and Steel, and have rightly been

described as the first great attempt at a just survey of our iron ore resources on a national scale. Amongst other labours which have been undertaken by Dr. Percy, and which have won for him a high place among discoverers in the metallurgic arts, were the determination of the effect of the Bessemer process on the composition of the metal, the production of aluminium from cryolite, the discovery of aluminium bronze, the chemistry of the amalgamation process, and the use of hyposulphite of soda for the extraction of silver.

Dr. Percy was greatly valued by Government and other official circles for his special scientific knowledge, in consequence of which he was called upon to serve upon a number of Government inquiries, including both the earlier commissions on armour plates, and the commission which dealt with Admiralty work only two years ago, under the presidency of Sir James Stephen. He was also a member of the Argyll Commission, appointed in 1866 to inquire into the extent and duration of the coal supplies of the United Kingdom, and he served on the Royal Commission appointed to inquire into the spontaneous ignition of coal cargoes.

Although Dr. Percy never received the official recognition of his labours to which he was undoubtedly entitled, his attainments and his work were greatly appreciated by scientific men. As a result and evidence of this, he was elected in 1885 the President of the Iron and Steel Institute, and served in that capacity for two years. He was also elected a fellow of the Royal Society, an honorary member of the Institution of Civil Engineers, and a member of the Athenæum Club. He was one of the first honorary members of the Iron and Steel Institute, and was awarded the Bessemer gold medal of the Institute in 1877. The Albert gold medal of the Society of Arts was awarded to him on the day of his death, and in 1887 he was awarded the Millar prize of the Institution of Civil Engineers, which, however, he desired to have spent on the purchase of a microscope, equipped under Dr. Sorly's direction, with the appliances for the study of the micro-crystalline structure of metals, to be at the disposal of any member of the Institution desirous of undertaking such studies, but who might be debarred from doing so by the costly character of the apparatus.

Dr. Percy was a man of strong physique and commanding presence, and he inspired very largely the respect, as well as the affection, of many distinguished students that he had the honour of training. Among his earlier students were Mr. G. J. Snelus, F.R.S., and Mr. Weston (who is now chemist to the Admiralty), Mr. P. C. Gilchrist,

Mr. Hilary Bauerman, and others who have taken a leading position in the metallurgical world.

Dr. Percy was a man of considerable literary and artistic attainments, which were evidenced by his possession of a magnificent metallurgical library in his house at Gloucester Crescent, and of one of the best representative collections of modern English water-colour artists extant.

Sir WILLIAM PEARCE, Bart., M.P. for the Govan district of Lanarkshire, and one of the most enterprising and successful shipbuilders of his time, died at his London residence in Piccadilly, on the 18th of December last.

Sir William Pearce was born at Brompton, in Kent, in the year 1833, and was thus in his fifty-sixth year. He learned practical shipbuilding in H.M. dockyard at Chatham, serving for a considerable time in the office of the late Mr. Oliver Lang, one of the most celebrated naval designers of that day. In 1861, when the Government determined upon the construction of iron ships in the royal dockyards, Mr. Pearce was the first officer selected to engage in that work. With other officers he superintended the building of H.M.S. *Achilles* in the dockyard at Chatham. He left the Government service in 1863 to become a surveyor under Lloyd's Register of Shipping, and was for a time employed in that capacity in the Glasgow district. In 1864, however, he was appointed manager in the shipyard of Messrs. Robert Napier & Sons, Govan, and here, in 1865, his ability as a naval architect was first brought into prominence through the designing of the steamships *Pereire* and *Ville de Paris*, built for the Compagnie Generale Transatlantique, which vessels maintained for several years a foremost place among the fast steamships on the Atlantic.

Shortly after the death of Mr. John Elder, in 1869, Mr. Pearce joined Messrs. John Ure and John L. K. Jamieson in carrying on and extending the shipbuilding and engineering business at Fairfield, under the title of John Elder & Co. In 1878, Mr. Ure and Mr. Jamieson retired from the firm, and Mr. Pearce became the sole partner, which position he occupied up till about two and a half years ago. In 1885, some little time after Mr. Pearce was returned to Parliament, the firm was formed into a limited liability company, under the title of the Fairfield Shipbuilding, Engineering, and Ordnance Company, Limited, with Mr. Pearce as chief director. As was stated at the time, Mr. Pearce's primary object in taking this step was to place the firm on such a basis as to be able, notwithstanding his position in Parliament, to undertake work for

the Government, and so maintain the prosperity of the district, just then suffering from great depression in trade.

During the period that Mr. Pearce was connected with the Fairfield Works, the tonnage of new shipping produced there amounted to over 450,000 tons. By far the greater portions of this total was made up of huge steamships, having powerful machinery, whose name and fame have long since become world-wide, including the *Arizona*, the *Alaska*, the ill-fated *Oregon*, the *Orient*, the *Austral*, the *Stirling Castle*, the *Umbria*, and the *Etruria*. The latter well-known ships had not been long in service before Mr. Pearce publicly maintained the possibility of producing a steamship capable of accomplishing the Atlantic voyage in five days, and intimated that he would not consider his life work done until this was realised. In the Glasgow Exhibition recently closed, the model of a steamship designed to accomplish this result was exhibited amongst the firm's other models.

Sir William Pearce constructed the entire Atlantic fleet of the North German Lloyd's, which includes seven of the ten fastest ocean-going steamers afloat, the whole of the New Zealand Shipping Company's fleet, which have brought the antipodes within thirty-six days of the mother country, and the fastest of the Orient fleet, which have brought Sydney within thirty-eight days of Plymouth. In channel steamers he was no less successful, and to him is due the fact that the passage between Dover and Calais can now be accomplished in less than an hour. His great capacity for work and his ceaseless energy, coupled with exceptional powers of organisation and judgment in the selection of men, resulted in the creation of a ship-producing establishment which, even as he lay on his deathbed, accomplished the extraordinary feat of constructing an Atlantic liner of 5000 tons in the short space of ninety-eight working days. It was owing to this admirable organisation that he was able, at the close of the Soudan war, to build in twenty-eight days eleven stern-wheel vessels for bringing the troops up the Nile, and to deliver them at Alexandria in two days less than the contract time. Concurrently with this contract, he built in twenty-one working days a hospital boat of larger dimensions than the other eleven, and he received the thanks of Lord Hartington, then Minister for War, for his services.

Several of the most modern vessels of Her Majesty's navy have emanated from the Fairfield stocks, amongst others the *Marathon*, which was named by H.R.H. Princess Beatrice in August 1888. Perhaps no other of Mr. Pearce's productions excited so much interest and curiosity as the memorable yacht *Livadia*, built for the late Emperor of Russia. This novel and extremely fantastic production was from the designs of Admiral Popoff, of the Russian navy, Mr. Pearce being responsible only so far as

e construction and propulsion at a stipulated speed were concerned. 'ith characteristic intrepidity, Mr. Pearce undertook to build and propel ıe ungainly craft at the desired speed, when many in the profession ıgarded its attainment as impracticable, if not impossible.

Sir William's death, technically ascribed to heart disease, is attributable ɔ a complete collapse of the nervous system, the result of the severe train of the work in which he has been engaged. He was elected the irst member of the newly-created constituency of the Govan Division ıf Lanarkshire in 1885, and again in 1886, having previously contested Hasgow in the Conservative interest in 1880. He was chairman of the Juion Steamship Company and of the Scottish Oriental Steamship Com-ɔany; he has been re-elected Deputy-Grand Master of the Province of Hasgow in the Masonic brotherhood since 1880; he was a Deputy-Lieutenant and Justice of the Peace for Lanarkshire, and he served on ihe Royal Commissions on Tonnage, on Loss of Life at Sea, and on the Depression of Trade. He was created a baronet in 1887, and is succeeded n the title by his only son, William George, who was educated at Trinity College, Cambridge, where he graduated M.A., LL.B., and was called to ihe Bar of the Inner Temple in 1885. Sir William was elected a member ɔf the Institute in 1882.

Major-General NICHOLAS KALAKOUTSKY was born in 1831, in the government of Smolensk. Like most of the children of noblemen of hat period, young Kalakoutsky was destined for the army, and com-nenced his military education at an early age in the college of the Nobility Corps. In 1849 he joined the artillery, and he took part ılmost immediately afterwards in the Hungarian campaign. He served luring the Crimean War, but in 1861 he retired from active service, in order ɔ devote himself to the study of the construction of ordnance. He was ient as a junior inspector to the metallurgical factories in the Ural, and vhile so employed he devoted much time to the study of foreign languages ınd to the foreign technical literature relating to the construction of artil-ery, to which branch of the service he now began almost exclusively to ıpply his attention. In 1870 General Kalakoutsky, who by this time ıad attracted the attention of the War Office by his extensive special echnical knowledge, was transferred to St. Petersburg, and ultimately he ɔecame chief inspector of guns and war material at the Abouchoff Steel-vorks, near St. Petersburg. He was, in addition, frequently consulted ıbout the construction of ordnance generally, so that it is hardly too much ɔ say that he bore an important part in the design and manufacture of ll the modern Russian artillery.

Residence in St. Petersburg gave General Kalakoutsky opportunities

of devoting himself to researches respecting the internal stresses developed in cast iron and steel. For sixteen years he pursued his patient investigations, mostly at his own expense, and by the aid of instruments of great accuracy constructed according to his own designs, and only so late as 1887 published the results of his labours in the Russian language. An English translation by Mr. W. Anderson,* member of the Iron and Steel Institute, appeared almost immediately in a series of articles in the *Engineer*, and a little later a French translation was published in the *Revue d'Artillerie*. The English translation has been reprinted, and will be found in book form in the library of this Institute. The conclusions Kalakoutsky arrived at, upon the basis of the measurements made, are that the internal stresses in gun tubes and hoops vary according to the manner in which they are manufactured, annealed, hardened, or tempered, that these stresses are often very severe, and so deleterious that spontaneous fractures arise without any additional stress being brought on by external forces. He showed how deleterious stresses might be converted into beneficial ones, and how the manufacture of new forms and patterns should be guided by exact preparatory measurements.

General Kalakoutsky's work brought him into constant relations with the gunmakers of Europe and of the United States, and involved him in a voluminous correspondence.

Besides the great work of his life, the subject of this notice contributed many articles to contemporary journals on matters connected with gunnery, and in 1866 he published a critical examination into the condition of British artillery. This able paper is probably unknown in this country. It contains, however, many valuable reflections and forecasts, and may be studied with profit, even now, by those who have to do with the supply of guns to the services.

In 1879 he carried out experiments on the pressure of powder gases in small bore guns and rifles, and obtained a premium in recognition of his services.

In 1884 General Kalakoutsky retired from the army, after thirty-five years' service of exceptional value to his country, but nevertheless he continued to render advice, both to the Ordnance Committee and to the Abouchoff Works, to the day of his death.

For some years his health had been failing. Disease of the heart was gradually undermining his strength. He sought relief in the mineral waters of Keeslovodsk, in the Caucasus, during the summer of 1888, and returned to St. Petersburg in the autumn much relieved. Too soon, however, his friends had the grief of seeing him grow weaker and weaker,

* Mr. Anderson has been kind enough to contribute this biographical notice of his deceased friend.

and he died on the 29th of January of the present year, leaving a widow and a very large circle of friends to lament the loss which the country had sustained. It is only those who had the privilege of his friendship who could appreciate the vast fund of exact knowledge possessed by the quiet unassuming man; it is only his intimate friends who can truly appreciate the loss which his premature death is to science in general, and to the art of gun construction in particular.

General Kalakoutsky had received several orders of distinction from his sovereign, and was an officer of the French Legion of Honour. He joined the Iron and Steel Institute in 1886.

RICHARD PEACOCK, M.P. for the Gorton Division of Lancashire, who died on Sunday, the 2nd day of March, 1889, was a self-made man. His father, Ralph Peacock, was originally a working lead miner in the West Riding of Yorkshire, but subsequently attained a responsible position on the Leeds and Selby Railway. The son was born in 1820, and one of his earliest recollections was the sight of the locomotive engines on the Stockton and Darlington Railway, then recently opened. He thereupon expressed a desire, and manifested a capacity, for locomotive engineering, and at the age of fourteen he was apprenticed to Messrs. Fenton, Murray & Jackson, who were locomotive engine builders, and who were at that time constructing engines for several lines of railway in Lancashire and Yorkshire.

After remaining with the firm named for rather more than four years, young Peacock was, at a remarkably early age, appointed locomotive superintendent on the Leeds and Selby line. Here, however, he did not remain long. A few years later he came to the metropolis, and made the acquaintance of Mr. (now Sir) Daniel Gooch and Mr. Brunel. In his twenty-second year he was appointed locomotive superintendent of the Manchester and Sheffield Railway. This post he filled for about thirteen years, and under his direction the subsequently well-known works of Gorton and Openshaw were established.

In 1834, Mr. Peacock joined Mr. Charles Beyer, then manager for Messrs. Sharp, Stewart & Co., as locomotive builders, erecting works for that purpose at Gorton. The business thus commenced gradually extended, until it became one of the largest in the United Kingdom. At the time of Mr. Peacock's death, the works of his firm were turning out some 200 locomotives per annum, paying over £100,000 a year in wages, and employing about 3000 hands. Mr. Peacock was all along the active manager of the concern, and on the business becoming the property of a limited company some five years ago, he undertook the office of chairman.

Mr. Peacock was a member of the Institution of Civil Engineers, and

took a leading part in the establishment of the Institution of Mechanical Engineers. He became a member of the Iron and Steel Institute in 1887.

JAMES HOWARD, formerly member for Bedford, and one of the leading agriculturists and agricultural machine makers in the United Kingdom, died suddenly in London, on the 24th January 1889, of apoplexy. Mr. Howard was in his sixty-fourth year, and had pursued an active life, both as a manufacturer, as a stock-breeder, and as a politician. He also took a great interest in the Patent Laws, holding that the present system of provisional protection for nine months, with power of extension to at least twelve, opened the door to jobbery and fraud, and that patentees should either have a short provisional protection, or should lodge a complete specification, as in America. Mr. Howard's Britannia Implement Works at Bedford were well known, and for many years they have been among the most extensive in the country.

Mr. Howard was for some time president of the Agricultural Implement Manufacturers' Association. He was a member of the Institution of Civil Engineers, and of the Institution of Mechanical Engineers. He had served as high sheriff of Bedfordshire, and was three times mayor of Bedford. He became a member of the Institute in 1881.

JOHN MUSGRAVE, who died at Eastbourne on the 4th April last, was a member of the firm of Messrs. John Musgrave & Sons (Limited) of the Globe Ironworks, Bolton. Deceased, who was in his sixty-ninth year, was the third son of the late Mr. John Musgrave, who founded the Globe Works, and had for many years taken an active part in the management of that business. He was the inventor of mechanical arrangements, some of them patented, which were of much service to the firm. At one time he travelled much on behalf of the business, and had a large connection in Russia, where he frequently made long stays. He became a member of the Institute in 1871.

JOHN M'MILLAN, one of the best known shipbuilders on the Clyde, died at Mentone, on Sunday, the 2nd December, 1888, in the forty-first year of his age. Mr. M'Millan was born at Dumbarton, where his firm have for many years carried on the shipbuilding industry successfully, in the year 1848. At an early age he began to take an active part in the administration of the works. He travelled much abroad, and was very successful in extending the business connections of the firm. In business he was prompt, methodical, and animated by strict integrity; and thus connections, once formed, were not readily broken. He was, moreover, very energetic, and quick in his perceptive faculties. He was a member

of the Institution of Naval Architects, and although he never read any papers there, he took great interest in its deliberations. In 1877, at a competitive exhibition of ships' models in the Fishmongers' Hall, London, under the auspices of the Worshipful Company of Shipwrights, a model which he designed and exhibited of a full-rigged sailing ship carried off the gold medal. Nor was the model in question a mere ideal one, for the *Coriolanus* was built by the firm on nearly the same lines, and proved one of the fastest sailing vessels afloat. In 1882 the same guild promoted another competitive exhibition, this time of an international character. The Messrs. M'Millan exhibited amongst other models those of the *Imberhorne* and *Falconhurst*, then building by them, and again carried off the gold medal. Mr. M'Millan shortly afterwards had the honour conferred upon him of being admitted a member of the Court of the Worshipful Company of Shipwrights. In other exhibitions, too, such as those of London, Newcastle, Edinburgh, and Glasgow, the models of Mr. M'Millan have been very much admired by competent judges.

The deceased was amongst the first to advocate and apply the principle of water ballast to sailing ships by means of double bottoms, and many vessels built at the works of his firm have had this special feature in all its thoroughness. When, some years ago, the question of unsinkable ships was agitating the minds of naval architects more than it is doing to-day, Mr. M'Millan exhibited in London the model of an unsinkable vessel, adapted for the transatlantic trade, which attracted much attention at the time. The vessel was of great size, and the designer claimed for her a high rate of speed, nearly absolute safety for voyagers and cargo, and large money returns to the owners.

Mr. M'Millan, about fifteen years ago, had a bad attack of rheumatic fever, and the evil effects of that malady were never completely eradicated from his system. In the spring of the year 1888 he was again attacked by rheumatic fever, accompanied by weakness of the heart's action, which greatly prostrated him, and for some time his life hung upon a slender thread. By-and-by, however, he rallied somewhat, and in October 1888 he was so far recovered as to be able to travel to Mentone, where it was hoped that through the influence of a more genial climate and complete rest he might once more be restored to his previous state of health. This hope was doomed to disappointment. Mr. M'Millan joined the Institute in 1886.

THOMAS JAMES, of Ivor House, Coatham, managing partner in the firm of Messrs. Maynard, Walker & Co., of the Redcar Ironworks, who died at Redcar in March last, was the only son of Thomas James, who came to the North of England in 1845 to erect the first blast-furnaces

for Messrs. Bolckow & Vaughan, at Witton Park, Durham, and who afterwards, in 1851, erected the Middlesbrough blast-furnaces and the Eston furnaces for the same firm. Whilst Thomas James, sen., was in the North of England building furnaces for Messrs. Bolckow & Vaughan and Messrs. Pease, Wilson & Co., the deceased gentleman was serving his apprenticeship under his uncle, Mr. Thomas Ellis, engineer of the Tredegar Ironworks, South Wales. On coming to the North of England, he worked at the Shildon Railway Shops, in the fitting department, and studied engineering generally. He was first connected with the blast furnaces of Messrs. Samuelson & Co., at South Bank, in the laying out of which he assisted, and was afterwards one of the managers for Messrs. Bell Bros., at Port Clarence. He left Clarence to manage the late Lord Londonderry's furnaces at Seaham, and in 1872 returned to the Middlesbrough district and undertook the management of the Acklam furnaces (Messrs. Stevenson, Jaques & Co.). On leaving that firm, he became a partner in the firm of Messrs. Walker, Maynard & Co., of the Redcar Ironworks, in which he continued to be managing partner to the time of his death.

The deceased gentleman took a great interest in various subjects connected with the iron trade. In local matters he also took a prominent interest, and on the formation of the Kirkleatham Local Board and the Kirkleatham School Board he was elected a member of these bodies. Two years before his death he was prostrated with a serious illness. He recovered somewhat, but after the death, about twelve months since, of a favourite daughter, he had a relapse, and gradually grew worse. He joined the Institute in 1872.

Edward Alexander Jeffreys was born at Shrewsbury on the 20th August 1824. He was the son of Mr. William Jeffreys, solicitor, a member of a well-known firm in that town. At the early age of fourteen he was sent as apprentice to the late firm of Bury, Curtis & Kennedy, of Liverpool, where all descriptions of railway plant and marine engines were manufactured. He there proved himself an energetic pupil, being principally employed in making the plans of locomotive and marine engines, and afterwards in superintending the working of them.

In 1845 he obtained the appointment of locomotive superintendent on the Shrewsbury and Chester Railway, being employed for the first fourteen months in superintending the construction of the rolling stock. This appointment he held for eight years, until the railway was absorbed by the Great Western.

In 1853 the late Mr. Thomas Brassey secured his services to go out to Canada as locomotive superintendent for the Grand Trunk Railway, and to take charge of the construction of the rolling stock before going out;

upon the opening of the Shrewsbury and Hereford Railway Mr. assey appointed him to manage and work that line for him during his se. This he did until its termination. In 1863 he obtained the appintment of general manager on the South-Eastern Portugal Railway, it after a few months resigned this appointment, on being offered the ost of manager of the Lowmoor Ironworks, which position he filled ntil Sir James Kitson, Bart., offered him a partnership in the Monkridge Ironworks in July 1879. He was subsequently connected with these works, first as a partner, and afterwards, when it was converted into a limited liability company, as a director.

Mr. Jeffreys had a very extensive acquaintance with railways and railway matters, and was regarded as an authority in matters of railway engineering.

He died at his residence, Hawkhills, Chapelallerton, Leeds, after a short illness, at the age of sixty-four.

JOHN LLOYD was born in North Staffordshire on the 23rd May 1825, and died on the 23rd March 1889. In early life he evinced a remarkable aptitude for mechanics, and was connected for some time with the Phœnix Foundry, Hanley, North Staffordshire. Afterwards he became resident engineer to the Lilleshall Company at Oakengates, Shropshire. He designed and erected their extensive engineering establishment, where he also constructed the first locomotive that was built in Shropshire, and specimens of his engineering ability and indomitable perseverance are to be found in many parts of the United Kingdom and abroad.

Mr. Lloyd induced the Lilleshall Company to lay down their basic steelworks at Priors Lee near Oakengates; but unfortunately, before their completion, he was compelled, some five years ago, to resign his appointment owing to ill-health. His connection with the Lilleshall Company extended over twenty-eight years.

Mr. Lloyd was of an active disposition, and shortly after retiring from Lilleshall, set himself to lay out the extensive saccharine works and docks of Messrs. Bostock & Co. at Garston, near Liverpool, in which concern he was a large shareholder. He also held the appointment of engineer to the Wirral Waterworks Company, Birkenhead, and was a director of the North Wales Narrow Gauge Railway Company. He died at his residence at Rock Ferry, Cheshire, in the sixty-third year of his age. He joined the Institute in 1876.

EDWARD JAMES GRICE was born at West Bromwich, on the 28th February 1834. His father was a member of the firm of Weston and Grice, of the Stour Valley Works, Staffordshire, where the son served an

apprenticeship of seven years, thereby acquiring a practical knowledge of the manufacture of iron. In 1872, after the works of Weston & Grice had become merged in the Patent Nut and Bolt Company, Mr. Grice became managing director of the Cwm Bran Works, belonging to that company, at Newport, in Monmouthshire. At Cwm Bran Mr. Grice remodelled the works, and, among other improvements and additions, constructed a tunnel of a mile and a half in length, in order to win coal that had been previously inaccessible.

Mr. Grice was chairman and director of several undertakings in the neighbourhood of Newport, including the Newport Slipway and Dry Dock Company. He was also one of the Board of Examiners for the South Wales district under the Coal Regulation Act. He was a J.P. for the county of Monmouth, and acted as Mayor of Newport in 1885. In the latter year he also acted as high sheriff and deputy-lieutenant for his county. Mr. Grice was a member of the Institutions of Civil and Mechanical Engineers, as well as of the Iron and Steel Institute.

Colonel PETER GRECK, who died at Moscow, Russia, on the 9th of May 1888, was born at St. Petersburg on the 23rd of November 1827. He was educated at the Imperial Engineering Academy in that city, where he greatly distinguished himself in his examinations. In 1848, on leaving the academy, he was appointed a lieutenant in the Imperial Corps des Ponts et Chaussées, and joined the locomotive service of the Petersburg-Moscow Railway. Subsequently he became resident engineer on a section of the Petersburg-Warsaw Railway, which he had partially constructed.

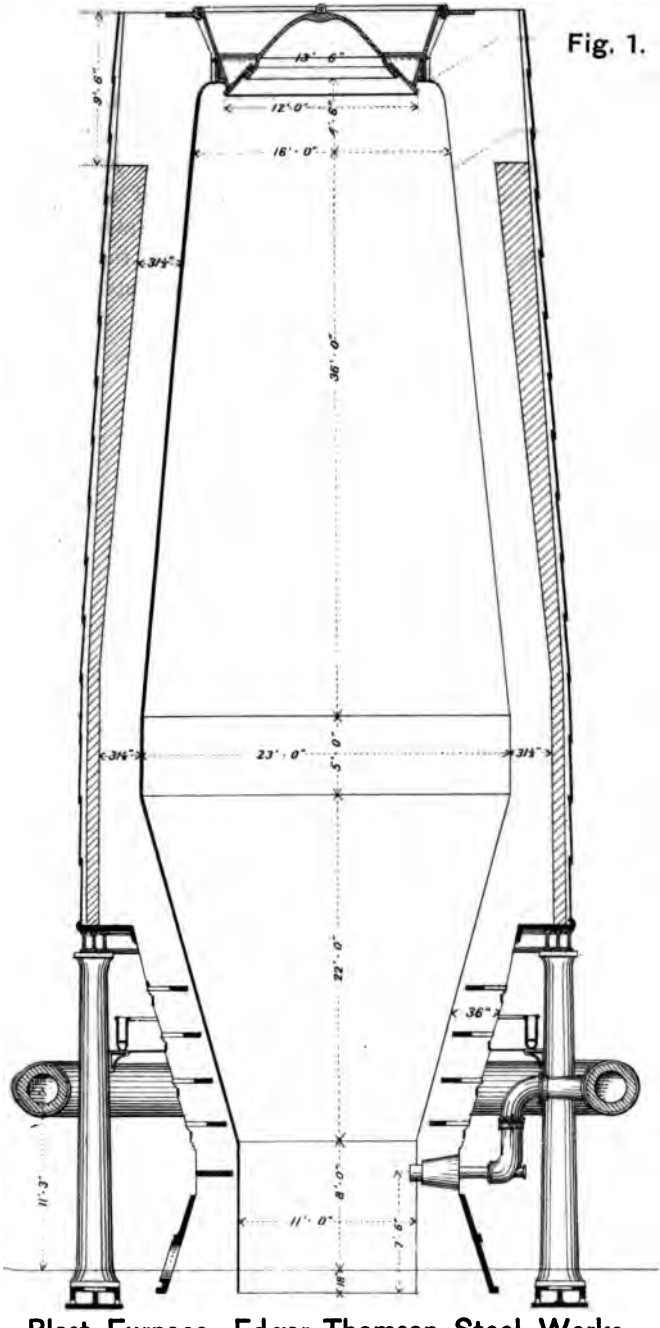
From 1860 to 1863, Colonel Greck served as aide-de-camp to the Russian Minister of Public Works. In the latter year he was entrusted with the general engineering control of the Petersburg-Moscow Railway at Moscow, and designed, in that capacity, the Central Station at Moscow, where he was located. For a number of years afterwards, Colonel Greck was engaged in railway work on a large scale, and between 1869 and 1881, he acted in London as chief engineer to the Russian Government. He was Commissioner for that State at the International Exhibition of 1874. On returning to Russia in 1881, Colonel Greck again took up railway engineering, and was engaged in that capacity at the time of his decease. He became a member of the Institute in 1871.

JOHN PHANUEL ROE, who died on September 9th last, at his residence, Consett House, at the advanced age of seventy-three years, was the chief engineer of the Consett Iron Company. He was born in

PLATE I.

TO ILLUSTRATE SIR JAMES KITSON'S ADDRESS.

Fig. 1.



Blast Furnace, Edgar-Thomson Steel Works.

f the Iron & Steel Institute

Ballantyne, Hanson & Co. Edinburgh & London.

progress of constructive work, such as the heavy incline and other plant designed and erected by Mr. Pearce Roe, who was then resident engineer.

Mr. Roe was a man who was known to his friends as possessing great breadth of knowledge and research. He was of a kindly, but somewhat retiring disposition, and a great lover of Nature. At the time of his death he was one of the oldest members of the Institution of Civil Engineers. He became a member of the Institute in 1875.

PLATE I.

) ILLUSTRATE SIR JAMES KITSON'S ADDRESS.

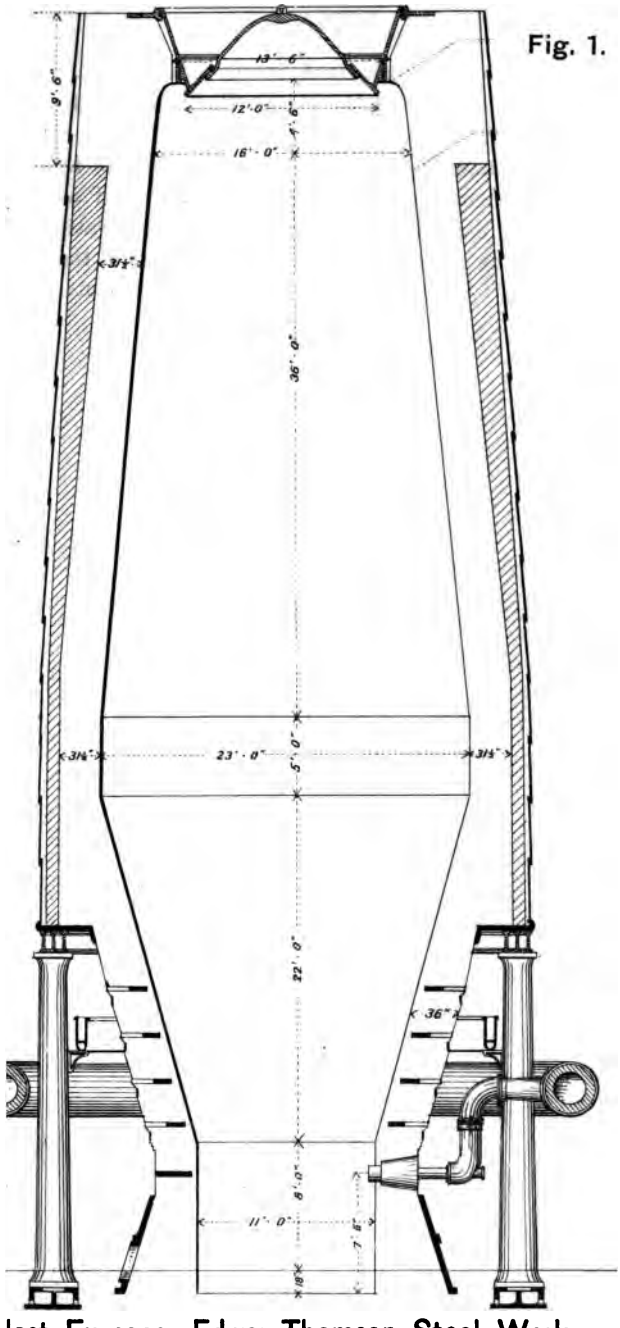


Fig. 1.

last Furnace, Edgar-Thomson Steel Works.

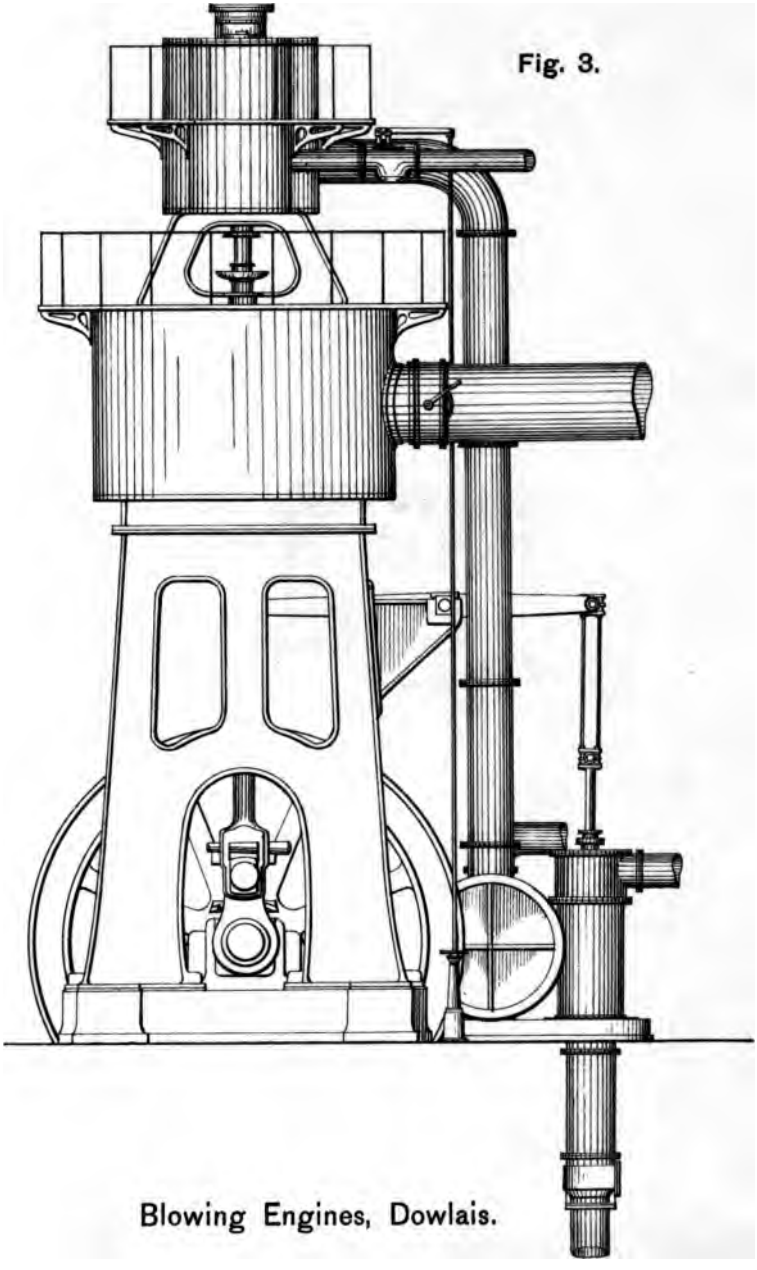
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'O ILLUSTRATE SIR JAMES KITSON'S ADDRESS.

Fig. 3.



Blowing Engines, Dowlais.

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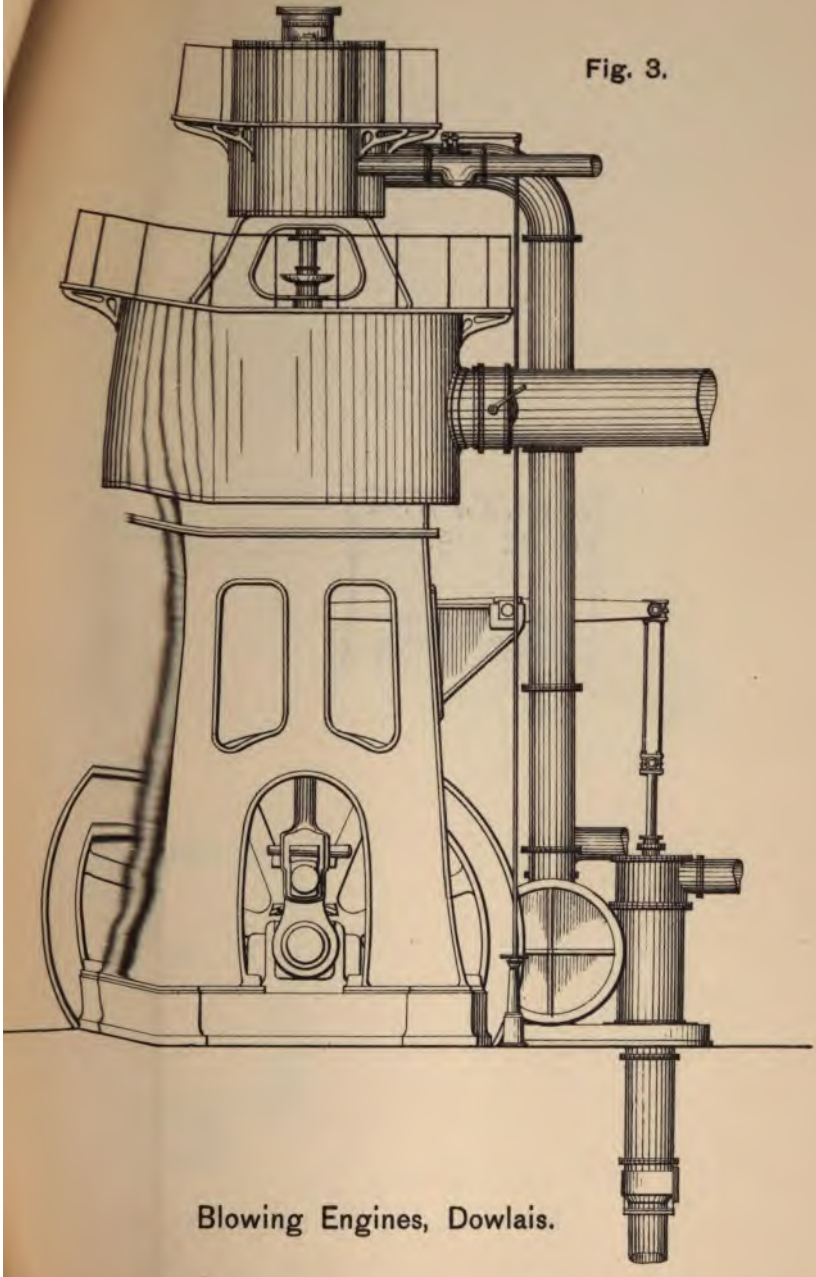
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PLATE III.

TO ILLUSTRATE SIR JAMES KITSON'S ADDRESS.

Fig. 3.



Blowing Engines, Dowlais.

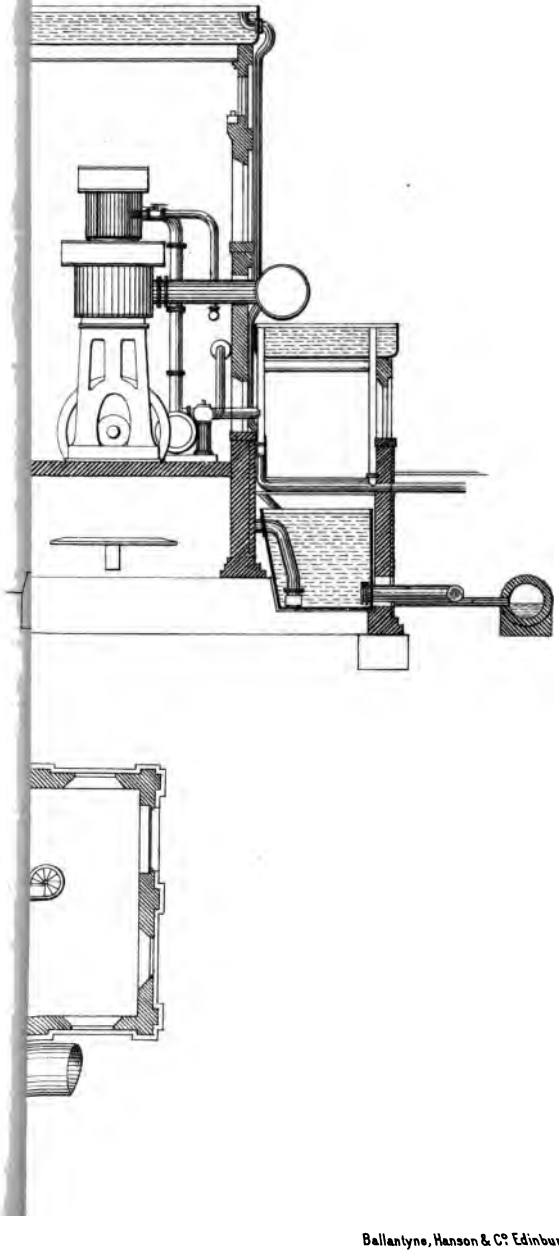
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)DRESS.

5. End Elevation.

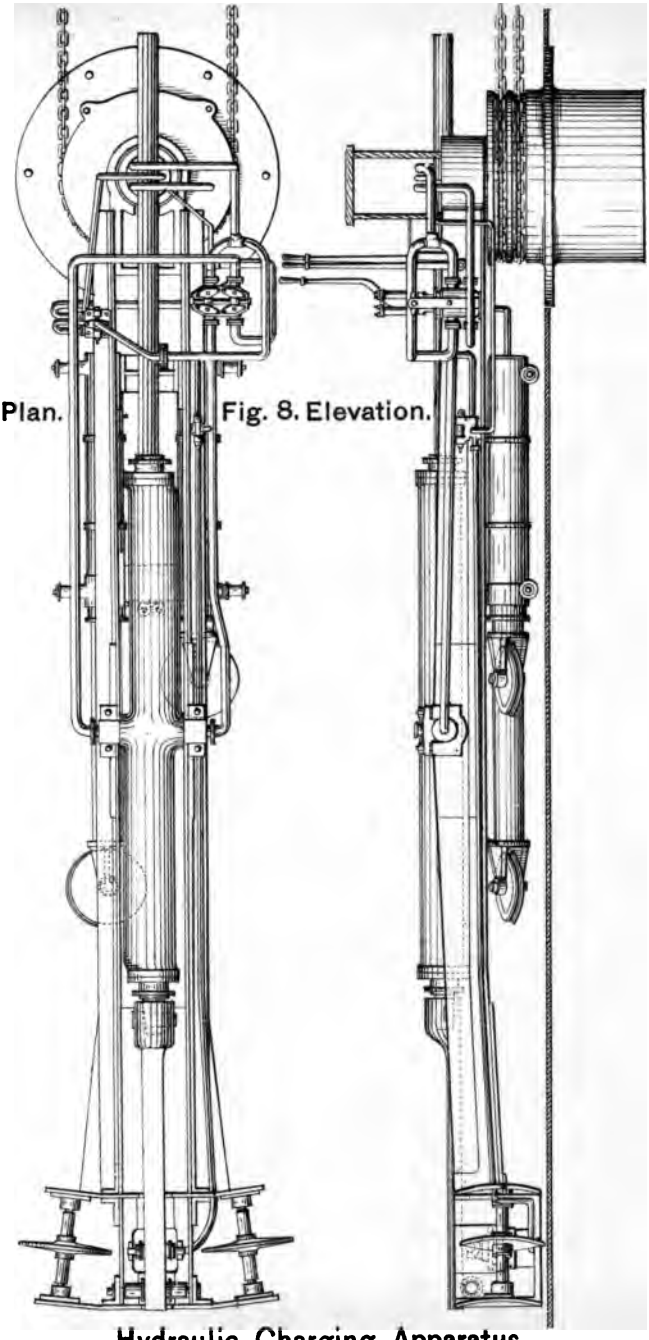


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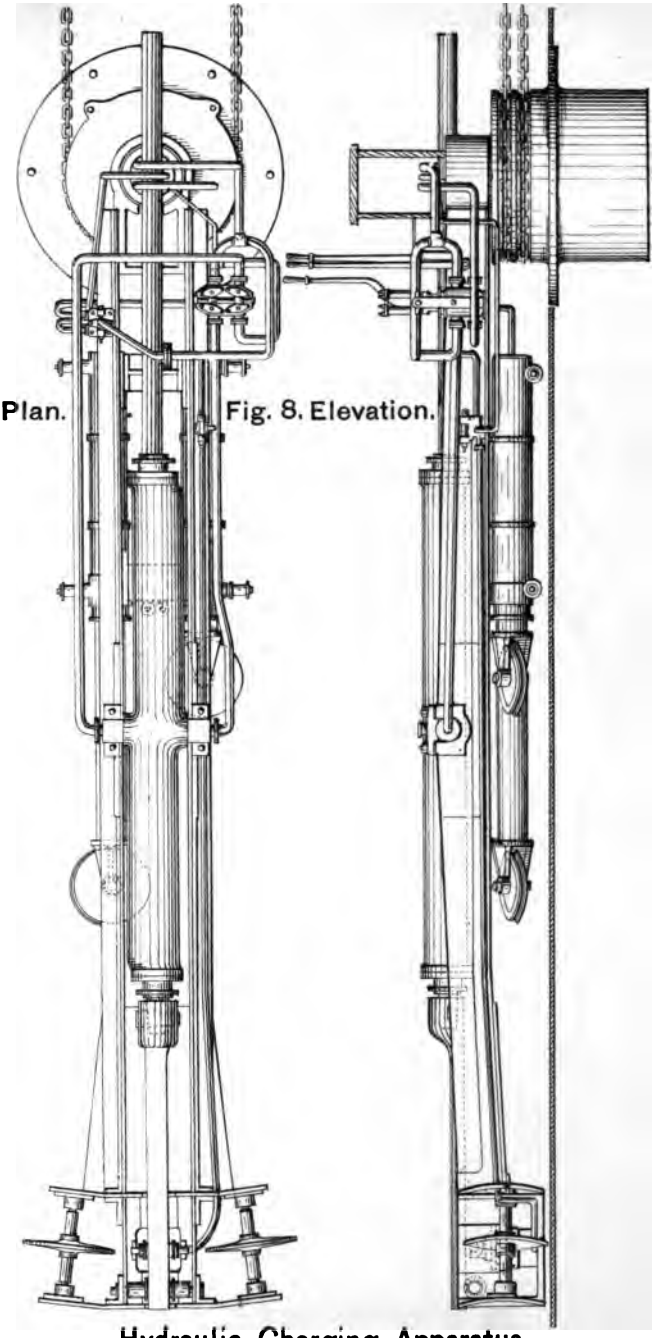
Hydraulic Charging Apparatus.

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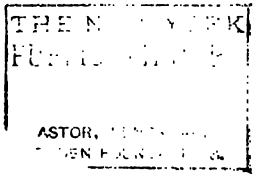
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TO ILLUSTRATE SIR JAMES KITSON'S ADDRESS.



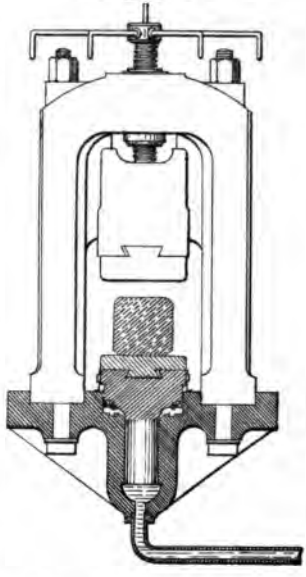
Hydraulic Charging Apparatus.

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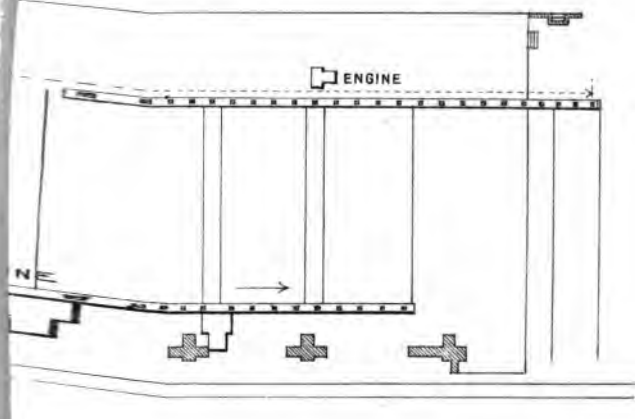

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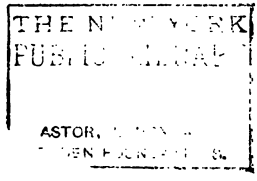
Fig. 18.



essemer Presses.

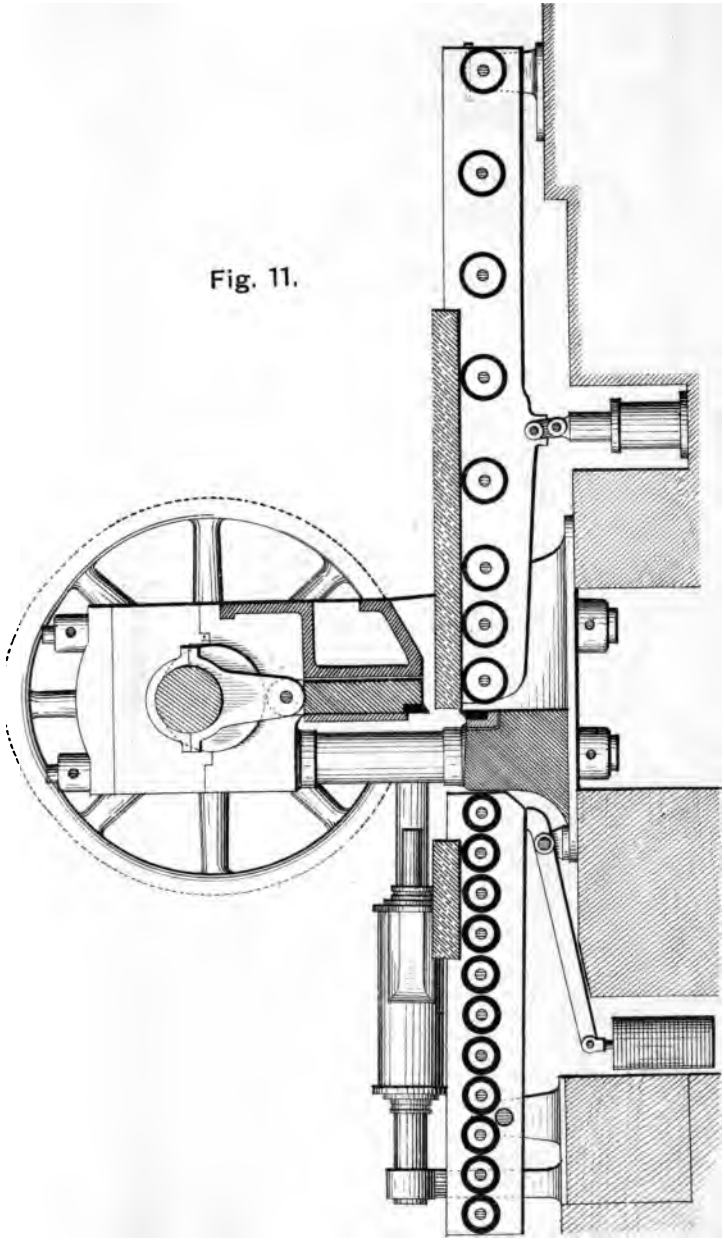


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Fig. 11.



Wicksteed's Shearing Machine.

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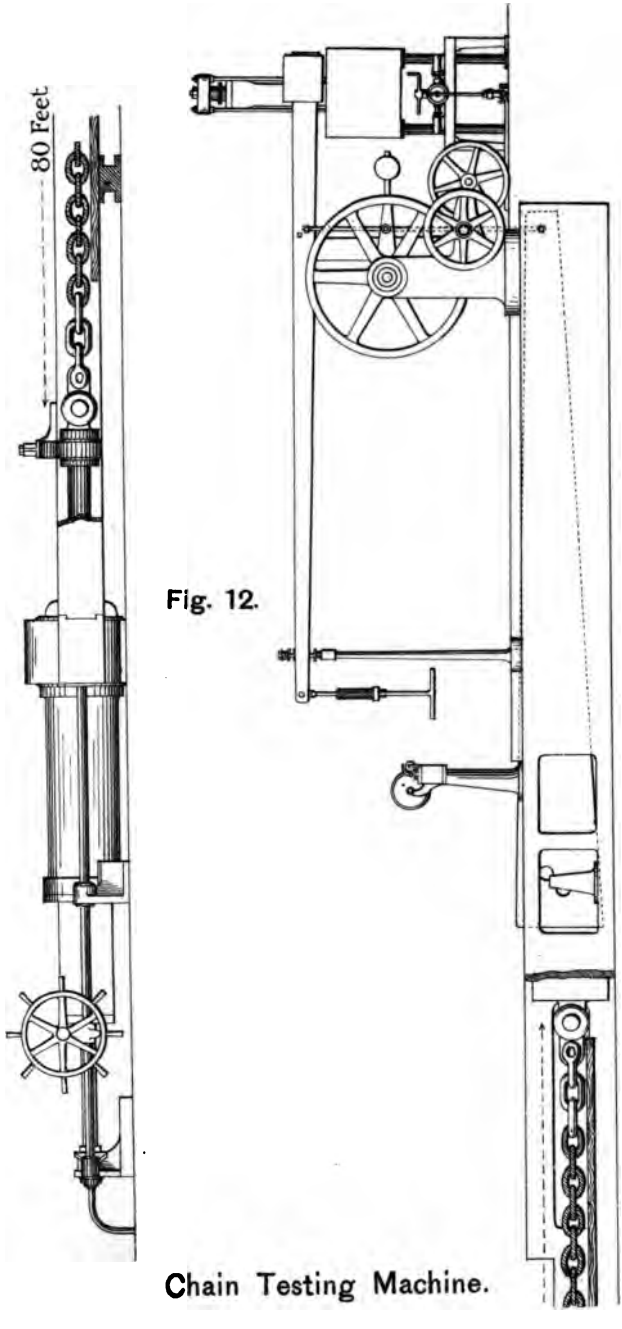


Fig. 12.

Chain Testing Machine.

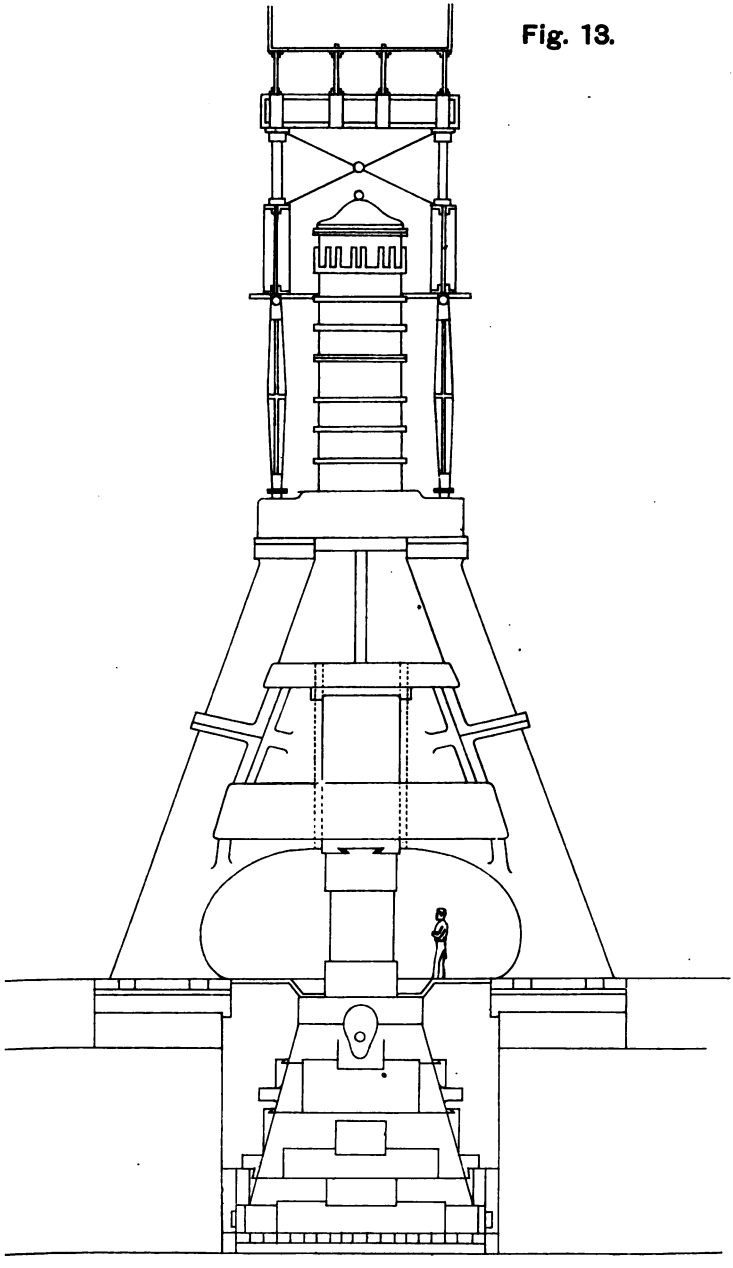
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Fig. 13.



100-Ton Hammer.

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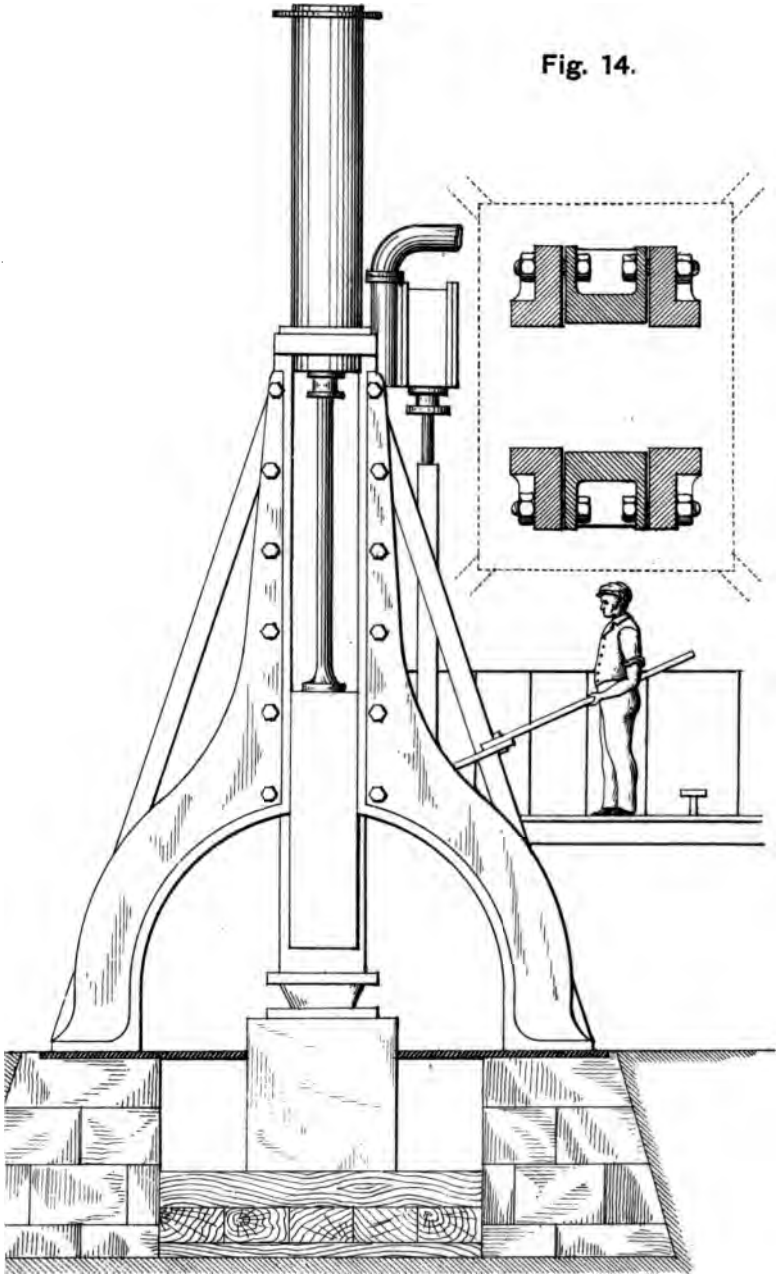
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PLATE XI.

TO ILLUSTRATE SIR JAMES KITSON'S ADDRESS.

Fig. 14.



Steam Hammer.

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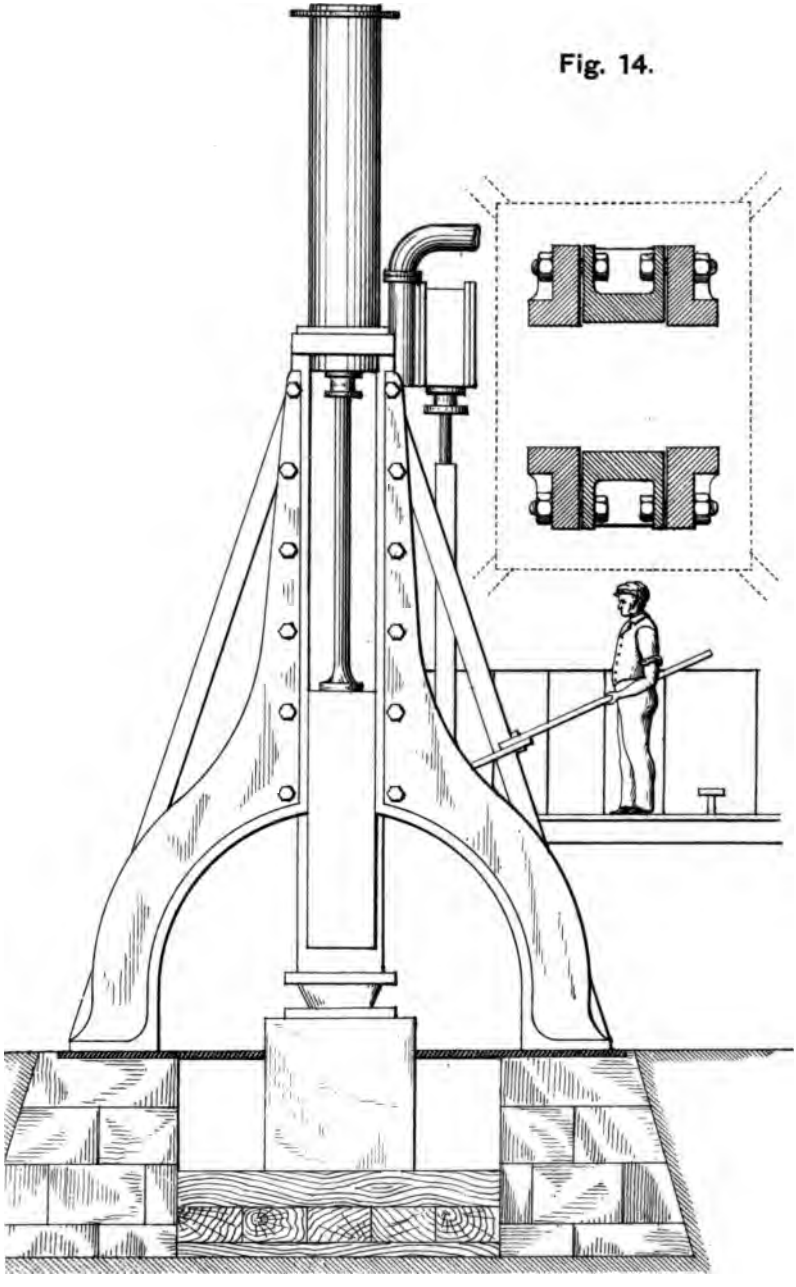
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PLATE XI.

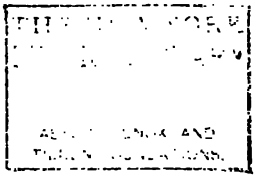
TO ILLUSTRATE SIR JAMES KITSON'S ADDRESS.

Fig. 14.

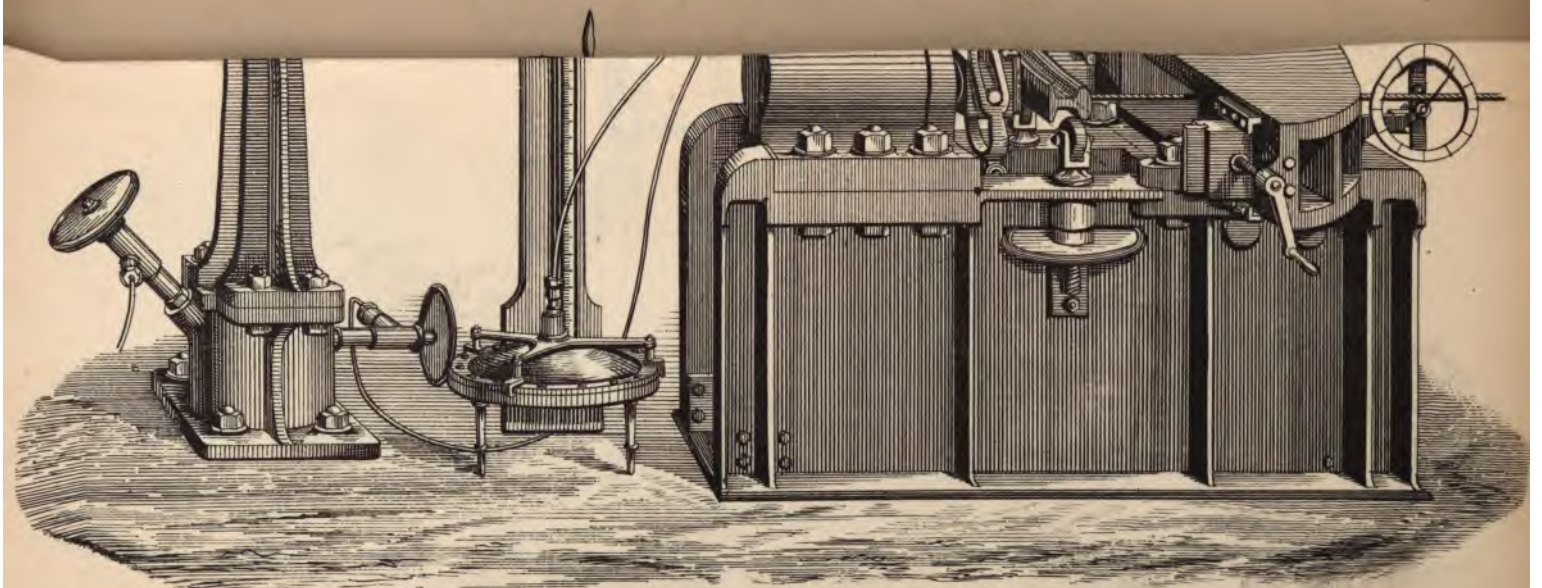


Steam Hammer.

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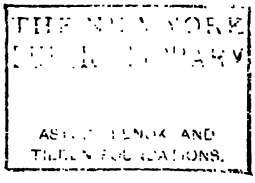
TO ILLUSTRATE M. GAUTIER'S PAPER.

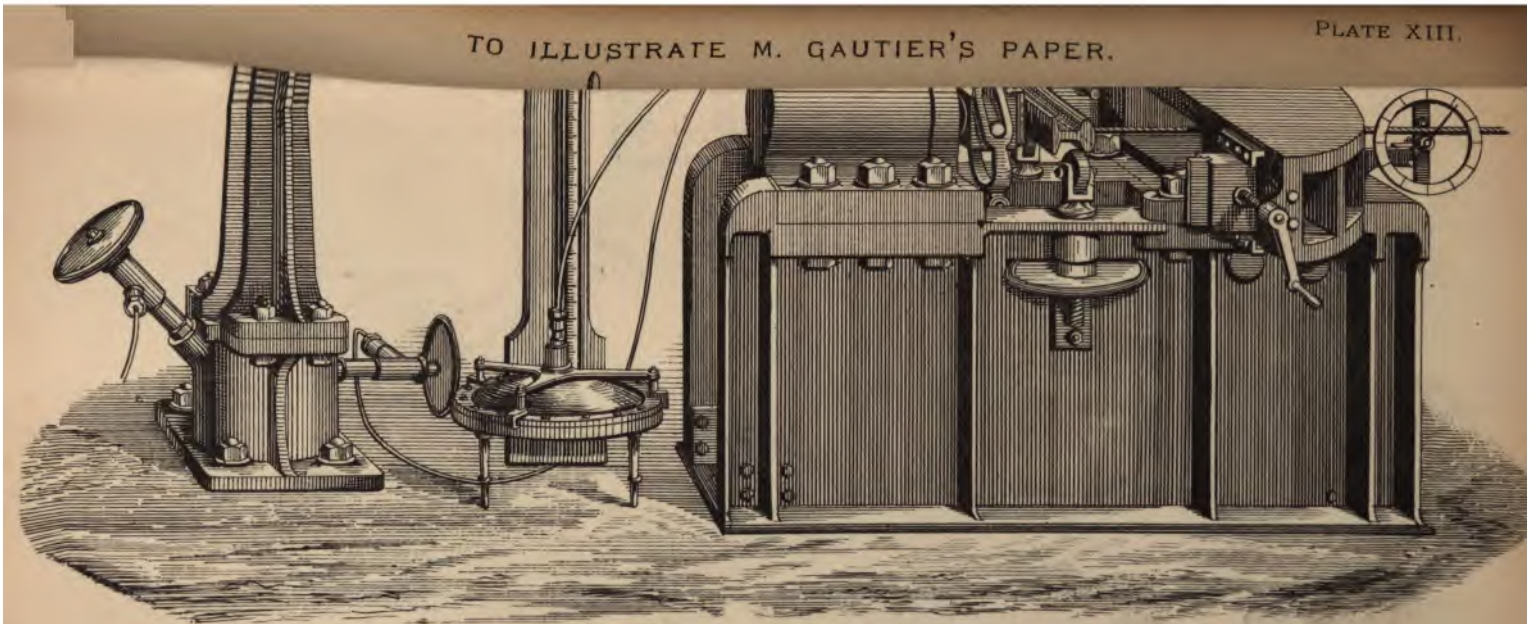


Thomasset 50-Ton Testing Machine for Bending Stress.

Journal of the Iron & Steel Institute

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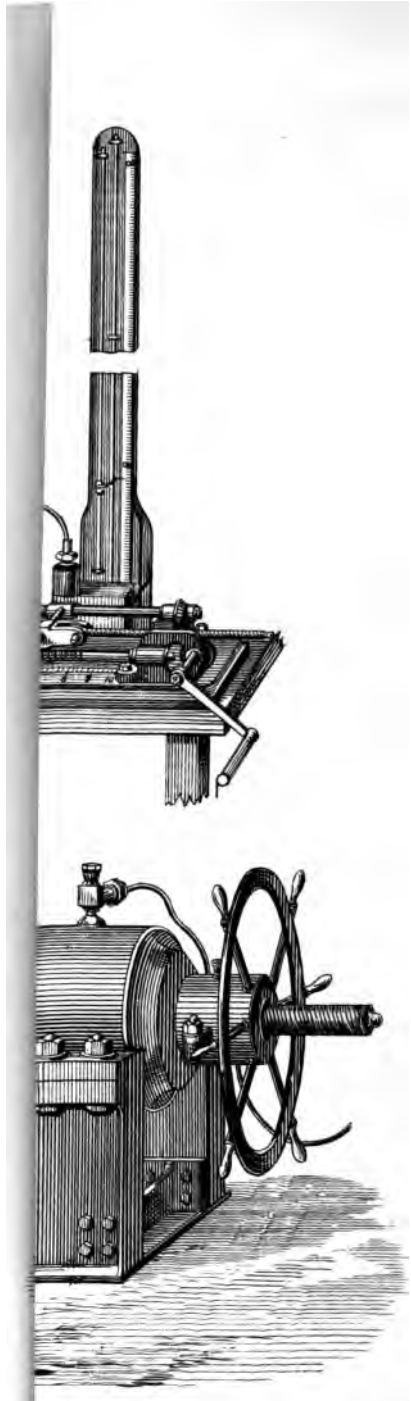
Thomasset 50-Ton Testing Machine for Bending Stress.

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PLATE XIV.



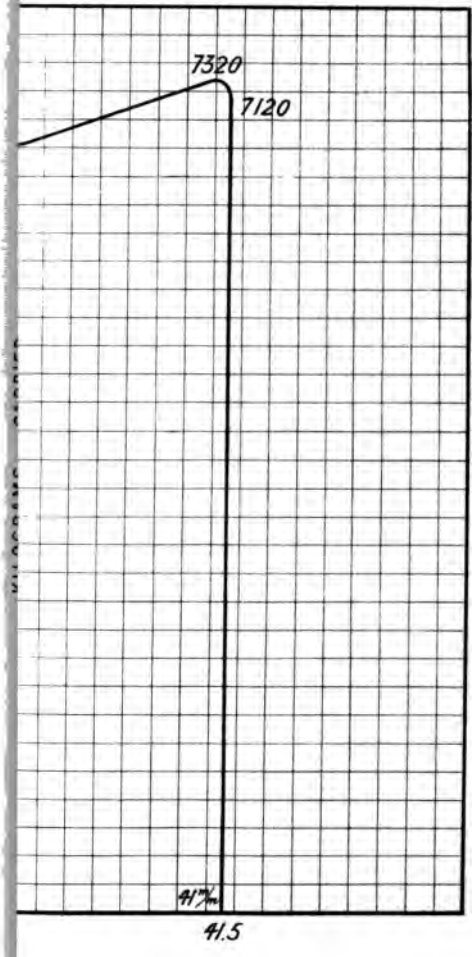
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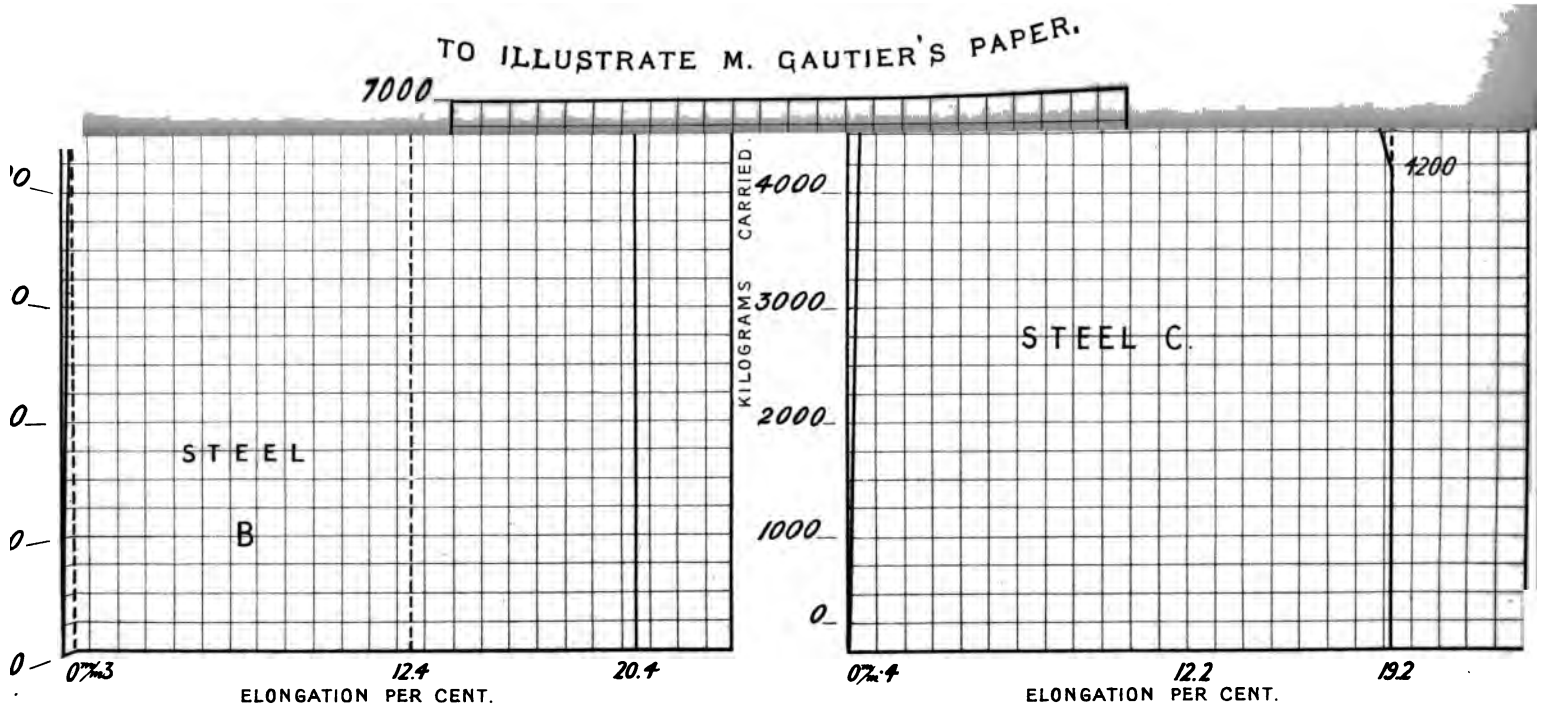
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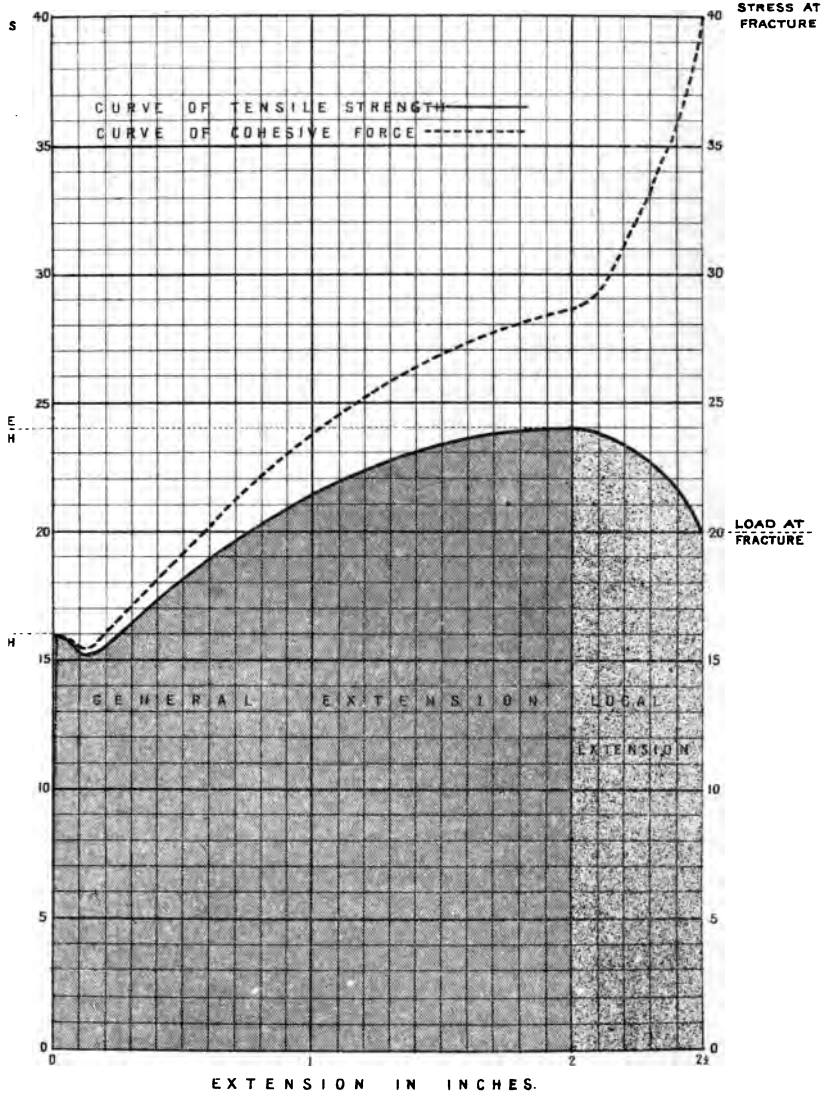
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PLATE XVII.

LUSTRATE MR. WICKSTEED'S REMARKS ON MR. GAUTIER'S PAPER ON THE THOMASSET TESTING MACHINE.

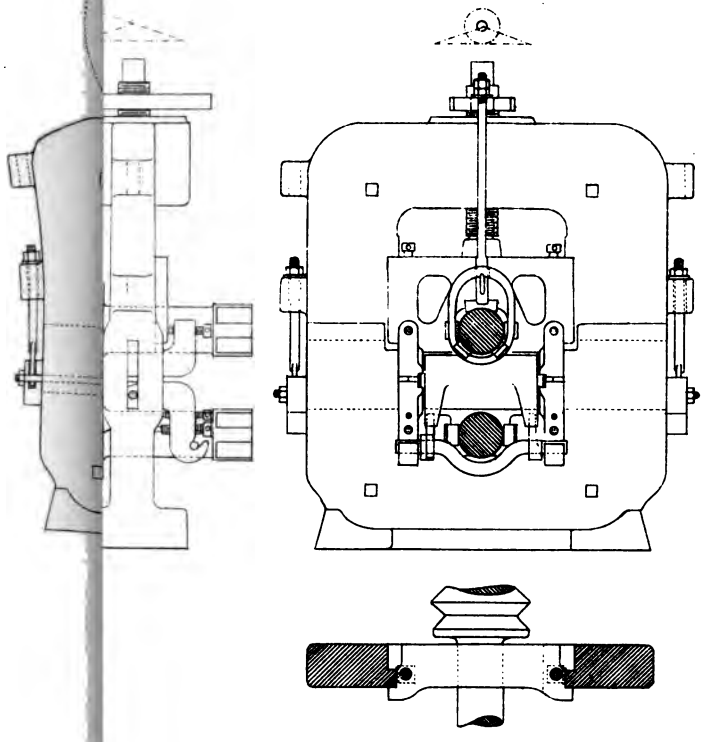


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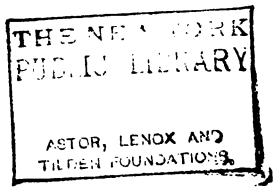
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PLATE XVIII.

ROLLING-MILLS."



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NOTES

ON THE PROGRESS OF THE

HOME AND FOREIGN

IRON AND STEEL INDUSTRIES.

I.—1889.

CONTENTS.

	PAGE		PAGE
Iron Ores	226	Further Treatment of Iron and Steel	352
Refractory Materials	249	Physical Properties	368
Fuel	250	Chemical Properties	383
Production of Pig Iron	294	Chemical Analysis	391
Production of Malleable Iron	325	Statistics	403
Forge and Mill Machinery	331	Bibliography	436
Production of Steel	339		

ABSTRACTORS.

EDWIN J. BALL, Ph.D.

BENNETT H. BROUGH, Assoc. R.S.M.

IRON ORES.

CONTENTS.

		PAGE
I.	Occurrence and Composition	226
II.	Iron Ore Mining	239
III.	Mechanical Preparation	240
IV.	Metallurgical Preparation	245

I.—*OCCURRENCE AND COMPOSITION.*

Iron Ore in New South Wales.—According to Mr. H. Wood,* the existence of extensive deposits of rich iron ores in various parts of New South Wales has been demonstrated in many cases in the vicinity of coal and limestone; but owing to the cost of erecting smelting works, and the difficulty of securing the necessary skilled labour, very little has yet been done towards developing the iron industry. Indeed, with the exception of the Fitzroy Works at Mittagong, the only works in the colony are those of the Eskbank Iron Company at Lithgow Valley, which, during the year 1885, produced bars and rails to the value of £23,972, and castings to the value of £1820.

Irregular masses and veins of magnetite, averaging 40·87 per cent. of iron, with garnet ironstone averaging 21 per cent. of iron, and some lodes of brown hæmatite containing 37·84 to 51·52 per cent of iron, occur in the Devonian beds near Wallerawang, whilst interbedded with the coal-measures, which extend from Wallerawang to Bowenfels, are several thin beds of rich clay-band iron ore yielding 49·28 to 56 per cent. of iron.

* Mineral Products of New South Wales, Sydney, p. 35.]

Loadstone in Sweden.—According to C. A. Vrang,* the ores of the Timansberg mining field, in the parish of Nora, occur, intercalated in gneiss, in two parallel beds coursing NNW. and dipping 30° to 35° ENE. In the western portion of the field has been found magnetite exhibiting the unusual property of attractive magnetism, fragments some 132 lbs. in weight being able to support a needle 2½ inches in length.

Iron Ore in Borneo.—According to Dr. T. Posewitz,† the iron ores of Borneo take a leading place amongst the mineral resources of the island. The ores occur chiefly in the form of clay iron ore, and as lateritic ore. Red hæmatite and magnetite are less generally distributed.

In South Borneo the red hæmatite of Tanah-Laut is of most importance. The ore is met with in ranges of hills extending from the sea shore for about fifteen geographical miles. The ore is hæmatite, but occasionally is strongly magnetic; it is crystalline, steel grey in colour, and has a red streak. By weathering it has become variegated in places, and exhibits a porous structure. Analysis shows it to be a very pure red hæmatite with slight admixture of magnetite. Foreign constituents (silica, lime, magnesia, and potash) do not exceed 2 per cent., whilst sulphur and phosphorus are absent. The ore contains 98 per cent. of ferric oxide, or 68·6 per cent. of iron.

Concretionary clay ironstone is found at numerous places in the coal measures, the principal deposits being in the west of South Borneo.

In West Borneo numerous deposits of clay ironstone have been discovered. Bog iron ore occurs at Batu, and in the river Swait. Brown hæmatite occurs in veins traversing the granite of the island of Karimata, where it has been worked by the Chinese. A similar vein occurs in the schist of Kandawangan. At Padjilu specular iron ore occurs in a vein 2½ feet in thickness, traversing schist in a south-easterly direction, and dipping vertically. The vein consists of a fine-grained aggregate of tabular crystals of specular ore, with some iron pyrites, magnetite, and tourmaline. In the clay state of Siluas and Sidin, pockets of specular ore are also met with. Iron has also been found in the native state in a grey siliceous schist on the Sikajam river, the rock containing 2·86 per cent. of iron. Under the microscope no crystals were observed, but only dark globular particles.

* *Geologiska Föreningen i Stockholm Förhandlingar*, vol. ix. pp. 243–246.

† *Borneo, Verbreitung der nutzbaren Mineralien*, Berlin 1889, p. 331.

In North Borneo iron ores are also widely distributed, chiefly in the form of clay ironstone nodules in the coal-measures. On the island of Labuan regular beds are sometimes met with in the carbonaceous shale. In Sarawak, too, iron ores are widely distributed, but not in sufficient quantities to render the working by Europeans profitable.

In the alluvium, fine iron sand is widely distributed throughout Borneo. It is always associated with gold in the placers. It is a mixture of chrome iron and magnetite sand, and is derived from ferruginous rocks. A specimen from a thick deposit, derived from serpentine, on the Pulu-Laut, gave on analysis the following results:—

Chrome iron.	Ferric oxide.	Sand.	Alumina.	Loss on Ignition.
23·434	63·550	9·771	2·987	0·258

Iron smelting has been practised by the natives in Borneo since the earliest times. Clay ironstone is the ore chiefly employed, being obtained from easily accessible places, such as river cuttings, where chemical action has partially converted the clay ironstone into an argillaceous brown hæmatite. The ore is, however, also worked by sinking small shafts. In the middle of the present century iron furnaces were scattered throughout the whole of Borneo, but since 1860, owing to the competition of European iron, iron smelting has been almost entirely abandoned.

The native furnaces were cylindrical, and had a height of 3 feet 4 inches, and a circumference of 10 feet. They were built of yellow clay, which was moulded to the required shape, and allowed to dry for a month. The smelting process never lasted more than a day. The blast was obtained from a hollow tree trunk, open at the top and closed at the base. The ore was first roasted, then broken into small pieces and charged into the furnace with charcoal in the proportion of 1 to 10. In 2½ hours the charge had sunk in the furnace, and more ore and charcoal were added. The slag was drawn off every twenty minutes; during this operation the tuyeres were removed and the blast stopped. Finally the iron was withdrawn from the furnace. The mass weighed 45 lbs., and was the product of the day's work of four men. It contained a quantity of slag, and was therefore re-heated after having been broken into ten pieces, and hammered until sufficiently pure to be sent to the smithy.

Though iron smelting has now been abandoned, there are still a number of armourers who make excellent swords. The natives prefer iron of home manufacture to European for this purpose, as their experi-

ence shows them that the sharpness and durability of weapons made from Borneo iron are greater than is the case with European.

Iron Ore in Burmah.—Dr. Noetling, of the Geological Survey of India, in a report on magnetic rock among the Shan Hills of Upper Burmah, describes a hill at Singaung which consists of a huge mass of iron ore. The hill covers an area of about a square mile, and rises 200 feet above the valley.

Iron Ore in Mexico.—According to Mr. R. E. Chism,* iron is fairly distributed, occurring in several districts in quantities large enough to make it of prominent importance in the future development of the country, and, perhaps, to materially affect the markets of the world in the not far distant future. The most important deposit is the Iron Mountain, at the gates of the city of Durango. This is an immense hill, one mile long, one-third of a mile wide, and rising at its highest parts from 450 to 650 feet above the surrounding plain. The ores are all oxides, and yield about 50 per cent. of iron in the blast furnace, and are reasonably free from phosphorus and sulphur. The next most important deposit is that found at Zimapan, in the State of Hidalgo. These deposits consist of oxide ores, principally magnetite. The iron in these ores is stated to vary between 30 and 80 per cent. They are likewise very low in sulphur and phosphorus. Experiments on a sample of iron made at this locality showed that the breaking weight for a section one inch square was 54,143 lbs., with an elongation of 0·238 per inch of length. In this locality there are six blast furnaces, of which four are in operation. The cost of mining a ton of ore at this place is rather less than 2s., and the deposit is worked by an open cut. The next most considerable production of iron is in the State of Jalisco. The ores found here are in great abundance, consisting principally of hæmatites, with an average of 65 per cent. of iron. They produce an iron which is said to be better than that of Sweden. There are two blast furnaces, and a bar mill capable of making $2\frac{1}{2}$-inch bars and all sizes of flats, $1\frac{1}{2}$-inch squares and various sizes down to $\frac{3}{16}$-inch round. Every description of castings can be made, from five lbs. up to four tons, but the workmen are especially skilful in making ornamental railings and chairs, sugar-boilers and small castings. The castings are made direct from the blast furnaces, or from cupola furnaces of poor construction when the blast furnaces are not in operation.

* *Engineering and Mining Journal*, vol. xlvi. p. 391.

The fuel used is charcoal of medium quality, which costs about £1 per ton. Mining costs from 2s. to 3s. a ton. In the State of Guerrero there are also extensive deposits of hæmatite iron ores with about 60 per cent. of iron. In the State of Oaxaca there are extensive deposits of magnetite and hæmatite, and five plants whose united product is about 450 tons annually in the form of flat, round, and square iron and billets. There is a large deposit of magnetite near Salome Botello Station on the Mexican National Railroad. There is also a deposit of iron ore, said to be of considerable extent, near Monclova, a town on the Mexican International Railroad, about fifty miles to the west of the last-mentioned deposit, and one in the Sierra of Santa Rosa, in the same State. In Chihuahua, iron is found in quantity in the cantons of Matamoros, Galeana, and Jiminez, in the State of Guanajuato, in the district of Leon, and in the State of Sinaloa, near the city of Culiacan. The annual total production of iron in Mexico may be estimated at 13,550 tons. Of this quantity probably 4500 tons are marketed in the shape of castings of different kinds, the remainder being wrought iron in the shape of rods and bars for blacksmiths' use.

The Iron Ores of Michigan and Wisconsin.—The Penokee-Gogebic series runs nearly continuously from the vicinity of Numakagon Lake, Wisconsin, to Gogebic Lake, Michigan, a distance of eighty miles. The series of rocks runs across the country in an approximately east and west direction. It is a simple series, which has been tilted to the north at an angle of 60° to 80°. The series rests upon a complex of granite, gneiss, and various green schists, and is overlain by the eruptive rocks of the Keweenaw series. According to Mr. C. R. Van Hise,* in the new mapping of the United States Geological Survey the series will be divided into four belts, the principal of division being a fragmental and non-fragmental character. At the base of the series is a cherty limestone-member which in one place is as much as 300 feet thick. The second member is a felspathic quartz-slate averaging 300 to 400 feet in thickness. It is composed of green, red, and brown fragmental slates containing a good deal of argillaceous matter. The upper part of this member is a pure vitreous quartzite. The third member of the series is a belt of non-fragmental sedimentary rocks, about 800 feet thick. This is known as the iron-bearing member from the fact that all the known ore-bodies occur within it. The uppermost

* *American Journal of Science*, vol. xxxvii. pp. 32–48.

member of the series is a thick layer of greywackes, mica-schists, and slates.

The origin of the ferruginous rocks and ores has been considered in a general way by Professor R. D. Irving, * his conclusion being that the original rock of the iron-bearing formation is a cherty iron carbonate from which the various phases of rock and the ore found in it have been produced by a complex series of alterations. This conclusion is borne out by the author's investigations.

The author then discusses at length the position of the ore in the iron-bearing member, (the dykes in the member, showing that if the vertical rocks were placed again in a horizontal position, the dykes would be vertical), and the position of the ore in reference to the dykes. The boundaries of the ore-deposits are to the south either fragmental quartzite or ferruginous quartz-rock in the ore formation. Under the ore are the dyke rocks, and above the ore the typical ferruginous cherts of the region.

The iron ore is a soft red somewhat hydrated hæmatite. By chemical analysis it is shown to be more or less manganiferous, the south deposits carrying more manganese than the north.

The shape of the deposits and their relations to the strata of the iron formation are such as to exclude the idea of original sedimentation in place; neither can they be considered as the result of oxidation of iron carbonate in place alone. It is, however, certain that the iron carbonates were the source whence the iron oxides for the ores were derived. The iron ores are thus necessarily concentrations of iron oxide, combined perhaps with iron oxide furnished by oxidation of carbonate in place. Passing through the ferruginous cherts, the percolating waters would quickly reach a dyke or the fragmental quartzite, and would follow along this barrier until it reached a trough made by the dyke and quartzite, along which it would follow, travelling towards the east as it penetrated deeper. Such water would be likely to contain oxygen in solution, and would be capable if it contained alkalies of taking up silica. Other water falling upon higher layers would make its way slowly through these less altered parts, and would oxidise iron carbonate until all the iron had been extracted from it. This oxidation of a part of the iron carbonate would liberate carbonic anhydride which would be taken into solution. Such water would take into solution unaltered iron carbonate. It would also in its upper course take up silica. As it penetrated further and took up more car-

* *Journal of the Iron and Steel Institute*, 1887, No. I., p. 314.

bonic anhydride and iron carbonate, it would be less able to carry silica, and would deposit that material as chert in the lower horizons. The water thus travelling on with an increased amount of iron carbonate would finally reach a dyke and be deflected towards the foot-wall quartzite. It would follow this dyke until the apex of the trough was reached. Here it would mingle with a larger amount of water, more capable of oxidising iron carbonate. The iron would thus be precipitated in the apex of the trough as more or less hydrated ferric oxide. These conclusions are in accord with the general conclusions arrived at by Mr. S. F. Emmons as to the origin of the ore deposits of Leadville, Colorado.

The Iron Ores of Minnesota.—Mr. J. Birkinbine * describes in detail the mining districts of Minnesota and the more important of the various mines. The annual output, the author shows, is dependent on the varying cost of freight from the mines to the blast furnaces. Two Harbours is the great centre for this traffic, and in 1888 the dock capacity has been largely increased, there being now two docks, with 206 ore pockets, having a capacity of 21,000 tons.

The Vermillion range has hitherto yielded all the iron ore which has been mined in Minnesota. The ore-bearing rocks extend from Tower, a point 70 miles north of Duluth, for a distance of 50 miles in a north-easterly direction to the Canadian frontier, and the jasper formation in which the ore is found may be traced across the frontier into Canada. The Messabi granite range, situated 15 miles south of the western end of the Vermillion range at Tower, trends more to the north, approaching the Vermillion range near the frontier of the Dominion. It extends further west than does the Vermillion range, and indications of magnetite ore have been observed at places at distances 30 miles west and 50 miles east of a point 55 miles due north of Duluth. The ore hitherto found in the Messabi range occurs in jasper or quartzites in a range of hills to the south of the granite range. The ore is chiefly magnetite, but hæmatite deposits also occur.

The Tower mine is one of the most important mines in Minnesota. A shaft has been sunk on this mine to the depth of 270 feet. The ore is partly "Red Lake" ore, containing 62 to 65 per cent. of iron, and partly Minnesota Bessemer ore in which the average percentage of iron is rather more than 67.

At the Chandler mine the output in 1888 is estimated at 40,000 tons.

* *Iron Age*, vol. xlii. p. 496.

The ore deposit at this mine is described by the author as a "gravel bank" of hard specular ore, whilst the Tower mines are quarries of compact masses of similar ore. The ore taken from the open workings is designated "long lake;" it contains 60 per cent. of iron, and but little phosphorus. A sample of ore, considered to represent an average for the whole of the deposit, was analysed with the following results :—

Iron.	Phosphorus.	Silica.
66·50	0·053	2·62

Other samples of ore were analysed, and gave :—

Iron.	Phosphorus.	Silica.
69·07	0·019	...
67·76	0·036	1·40
69·00	0·018	0·82
66·79	0·036	4·07
68·73	0·050	1·13
66·23	0·058	2·60

The samples were dried before being analysed, but the ore contains very little water.

Up to the present time the only deposits of iron ore that have been opened up in Minnesota are such as are classed as Bessemer ore. Iron-works are, however, now being established at Duluth, at the head of Lake Superior, and pipe-works at West Superior, Wisconsin, and it is anticipated that the comparatively poorer deposits of ore will soon begin to receive attention. Some of the magnetites of the Messabi range are found to contain considerable quantities of titanium, but it is pointed out that in the Lake Champlain districts deposits of both titaniferous and non-titaniferous, Bessemer and non-Bessemer magnetites occur close to one another.

Iron Ores near Bristol, Tennessee.—The iron ore deposits found in the land adjacent to the South Atlantic and Ohio Railway, which extends for a distance of 40 miles north-west of Bristol, Tennessee, are of several varieties. In a report by Mr. J. R. Proctor, the State geologist of Kentucky, it is stated that a deposit of red fossil, or Clinton ore lies parallel with the railway for a distance of 14 miles. The deposit is stratified; there are three beds of ore of considerable thickness, the total quantity of ore being so considerable that it is estimated that 20,000,000 tons of it could be mined at a cost of from 2s. to 4s. the ton. The ore averages from 45 to 54 per cent. of iron. The railway is being continued towards Big Stone Gap, and on the line of this extension a deposit of a good variety of limonite has been

found, the quantity of ore being so great that Mr. Proctor believes the amount to be larger even than that of the Clinton ore already mentioned. The horizon of this ore is the Oriskany of the Upper Silurian. The ore contains from 50 to 55 per cent. of iron, and but little silica or phosphorus. A number of other deposits of ore have also been found along the proposed route of the railway. They include: 1. Masses of rich ore in the Trenton and Knox limestones, the ore in one instance being of Bessemer grade; 2. Pockets of ore in Medina sandstone; and 3. Stratified ore, 2 feet in thickness, in Chemung shales. Immediately to the south-east of Bristol, at a distance of 2 to 7 miles, are large deposits of semi-magnetic ore containing from 55 to 60 per cent. of iron and very little phosphorus. There are also large deposits of specular and other iron ores, and of manganese ore at various places in the neighbourhood of the railway.

Iron Ores from the Vermillion Range.—The following are some analyses of iron ore from the properties of the Minnesota Iron and Land Company, United States:—

Samples.	Iron.	Silica.	Sulphur.	Phosphorus.	Titanium Anhydride.	Manganese.
1	63·78	5·71	0·106	0·078	None.	Undetermined.
2	63·05	6·54	0·132	0·072	None.	„
3	27·37	58·06	0·334	0·067	None.	„
4	27·11	56·73	0·042	0·058	None.	„
5	32·82	51·90	0·176	0·048	None.	„
6	38·79	21·26	1·620	0·112	None.	„
7	51·77	21·75	0·206	0·009	None.	„
8	42·68	23·19	0·292	0·046	0·34	„
9	49·04	24·23	0·283	0·095	None.	„
10	57·73	0·99	0·101	0·022	16·64	0·219
11	40·67	23·29	0·145	0·005	None.	0·348
12	43·33	30·33	0·188	0·022	None.	0·653

The samples were taken from the outcrops of the lodes.

The St. Croix Range, Wisconsin.—Mr. P. A. Gough * gives the following analyses of iron ore from the Arthur mine, situated in the St. Croix Range, near the town of Wilson:—

	Fe.	Mn.	P.	S.	Al_2O_3.	CaO.	MgO.	SiO_2.	H_2O.
I.	54·81	1·82	0·13	0·02	1·33	...	...	7·96	9·33
II.	55·50	1·67	...	...	...	...	...	9·30	...
III.	54·85	1·21	0·09	0·02	2·41	0·99	0·14	6·66	10·60

* *Iron Age*, vol. xliii. p. 21.

The output of the Arthur mine in December 1888 was 60 tons a day. The ore deposit can be traced east and west for several miles; it is about 2 to 2½ miles wide. Underlying the iron ore is a deposit of fairly good manganese ore.

Manganese Iron Ore in Greece.—At the Laurium mines in Greece there was produced in 1887 about 24,000 tons of a manganiferous iron ore, containing 16·5 per cent. of manganese sesquioxide and 33 per cent. of iron. On the Island of Seriphos, iron ore is mined which contains about 47 per cent. of iron and 2·5 per cent. of manganese. Nearly the whole of the output is sent to Philadelphia. Iron ore is also found in Thermiæ, but only in small quantity. Coal is mined near Kumi in Eubœa, the output being about 6000 tons a year.*

A Russian Manganese Ore.—The following is an analysis of a manganese ore used in the Nischni Tagil Ironworks, in the Ural, for the manufacture of ferromanganese: †—

Mn_3O_4.	Fe_2O_3.	Al_2O_3.	CaO.	MgO.	SiO_2.
58·43	17·40	7·30	0·57	0·35	15·90

Formation of Deposits of Manganese Ore.—In view of the results of a series of fifteen experiments made by Mr. F. P. Dunnington,‡ it appears possible that many deposits of manganese ore in calciferous rocks have been formed by the action of solutions of sulphates rather than of bicarbonates. An illustration of such action is perhaps afforded by the manganese deposits of Crimora, Augusta Co., Virginia, where the upper portion of the formation is composed of decomposed shales, interspersed with calciferous ledges. In the shales, there occur pure neutral iron ores, free from manganese, and associated with them are manganiferous limonites, and also psilomelane of high grade, frequently appearing to have been produced under similar conditions, and sometimes the same mass is composed in part of manganese and in part of limonite. South of the Potomac, no pyrites is visible in these shales, possibly owing to the great depth to which they have been decomposed; but at Harper's Ferry, the iron ore lying in the same geological horizon has been worked down until compact pyrites has been reached.

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxvii. p. 34.
† *Stahl und Eisen*, vol. ix. p. 101.
‡ *American Journal of Science*, vol. xxxvi. pp. 175-178.

Assuming that pyrites existed extensively in the shales, the deposition of ores may be assumed to have occurred in the following manner: Where pyrites has been deposited, the outcrop is gradually converted into limonite by weathering, and the acid solution of ferrous sulphate, which sinks into the underlying deposits, must carry with it all the manganese in the pyrites itself and in any disintegrating silicates. As this solution is exposed to the air, or meets with calcium carbonate, ferrous carbonate will be formed, whilst the manganese sulphate will remain in solution until exposed to the action of both air and calcium carbonate at the same time.

Artificial Production of Chrome Iron Ore.—S. Meunier * has produced chrome iron ore artificially by strongly heating in a crucible an intimate mixture of 148 grammes of potassium dichromate, 58 grammes of ferrous carbonate, and 56 grammes of iron filings. The black molten mass is treated with water to remove the alkaline carbonate, and then with concentrated acids to remove the ferric oxide. A black non-magnetic amorphous residue remains. In order to obtain this product in a crystalline form, the crucible is lined with some finely-powdered cryolite, and the substance covered with a thin layer of the same mineral. The molten and powdered mass is then seen under the microscope to consist almost entirely of small octahedra.

Recent Researches on Meteorites.—M. Jerofeieff and P. Latschinoff † describe the meteorite, which fell on September 22, 1886, near the village of Nowo-Urei, Government of Pensa, Russia. It is unique in containing carbon in the form of diamond. Its chief constituents are olivine, augite, and nickeliferous iron. In the course of the analysis from 2 to 2·5 per cent. of the material taken remained unattacked by acids, and of this 60 per cent. was amorphous carbon, and 40 per cent. resisted fusion in potassium bisulphate. The residue was in the form of light grey grains, consisting of 89·6 per cent. of carbon, and 10·4 per cent. of ash. It had a specific gravity of 3·1, and a hardness sufficient to readily scratch corundum. This diamond-like carbon made up about 1 per cent. of the whole meteorite, which, on analysis, gave:—

Iron and Nickel.	Chromium oxide.	Fe_7S_8.	Carbon.	Silicate.	Total.
5·47	0·95	0·43	2·26	90·76	99·87

* *Comptes Rendus de l'Académie des Sciences*, vol. cvii. pp. 1153–1154.

† *Materalien zur Mineralogie Russlands*, vol. x.

As regards the occurrence of the carbon in the form of diamond the only related cases are those of the Arva iron, in which occur cubic crystals of a graphitic substance, thought by some to be pseudomorphs of graphite after diamond, and the related graphitic mineral, cliftonite, from the Youngdegin iron recently described by Mr. L. Fletcher.*

According to Mr. O. A. Derby† seven Brazilian meteorites are represented in the National Museum of Rio de Janeiro, of which only three have been previously described. The new ones are: *Itapicuru-mirim*, chondrite dating from 1879—weight, 2·024 grammes; specific gravity, 3·638. *Santa Barbara*, chondrite fallen on September 26, 1873—weight, 93·211 grammes; specific gravity, 3·478. *Minas Geraes*, chondrite, date of fall unknown—weight, 1·224 grammes; specific gravity, 3·5. *Angra des Reis*, augrite fallen in January 1869—weight of a quarter of the original mass, 446·5 grammes; specific gravity, 3·45; composition: augite, 93·28; olivine, 5·45; magnetic pyrites, 1·27.

The masses of iron known as the Santa Catherina meteorite were found scattered over a triangular area of 10,200 square metres, at a distance of about three miles from the city of São Francisco do Sul, on the island of the same name. No evidence could be found, in the vicinity, of the existence of basic eruptive rocks, such as are required by the hypothesis that the iron is similar in origin to that of Ovifak. On the whole, the evidence, though not conclusive, is in favour of the meteoric rather than the terrestrial origin of the iron.

The famous mass of iron known as the Bendego meteorite was landed in Rio de Janeiro on June 15, 1888, and is now in the National Museum of that city. The iron weighs 5·361 tons, and was transported over 70 miles of mountainous country to the nearest railway station. The comparative thickness of the crust of oxide formed since the first attempt to remove it in 1785, and that found in the original resting-place, afford a basis for a rough guess at its age, which is put down as over six centuries.

The meteorites of Djati-Pengilon in Java have been found by A. Daubrée‡ to consist of 5·1 per cent. of troilite, 33·4 per cent. of olivine, 39·0 per cent. of bronzite, and 21·3 per cent. of nickeliferous iron, composed of—

Iron.	Nickel.	Cobalt.
88·68	10·78	0·54

* *Journal of the Iron and Steel Institute*, 1887, No. II., p. 230.

† *Revista do Observatorio, Rio de Janeiro; American Jour. Science*, xxxvi. 157-8.

‡ *Comptes Rendus de l'Académie des Sciences*, vol. cv. p. 203.

Mr. G. F. Kunz* states that on August 9, 1884, at Glorieta Mountain, Santa Fe County, New Mexico, three large masses of meteoric iron were found. An analysis of one of the pieces gave the following results:—

Iron.	Nickel.	Cobalt.	Phosphorus.	Total.
87·93	11·15	0·33	0·36	99·77

Carbon and other constituents were not determined. The specific gravity was 7·66.

Mr. Kunz† also describes a mass of meteoric iron found in 1882 on Linville Mountain, Burke Co., North Carolina. The meteorite weighs 428 grammes, the original weight having been 442 grammes. It is $2\frac{3}{5}$ inches long, $1\frac{3}{5}$ inch high, and $2\frac{1}{2}$ inches wide. One side is rather rough and the other covered with very shallow pittings. Traces of the black crust of magnetic oxide are still visible. The iron admits of a very high polish, and under the lens and by reflected light appears to be a network of two distinct bodies. On analysis it gave the following results:—

Fe.	Ni.	Co.	S.	C.	P.	Total.
84·56	14·95	0·33	0·12	trace	trace	99·96

It most closely resembles the Tazewell (Claiborne Co.) and Bear Creek meteorites in composition.

In 1887 a mass of meteoric iron was found in the Silver Crown district, Laramie Co., Wyoming. When found it was half buried in decomposed granite and earth. In shape it somewhat resembles an anvil. It weighs 25·61 lbs. The surface is still covered with the original crust of magnetic oxide, and is irregularly pitted. This iron belongs to the Braunite group of Meunier. Analysis gave the following results:—

Fe.	Ni.	Co.	P.	C.	Total.	Sp. gr.
91·57	8·31	trace	0·07	trace	99·95	7·63

In composition it most closely resembles the Rowton, Charlotte, and Jewel Hill meteorites.

* *Engineering and Mining Journal*, vol. xliv. p. 22.
† *American Journal of Science*, vol. xxxvi. pp. 275–277.

II.—*IRON ORE MINING.*

Iron Ore Mining at Bilbao.—A lengthy paper on the iron industry of Bilbao has been published by E. Gruner.* It describes the improvements of the port of Bilbao, the ore deposits, the various grades of ore, geological structure of the district, history of the mining industry, mining legislation, methods of mining, means of transport, and statistics. The Bilbao ironworks are also described, and the paper concludes with a useful bibliography of the subject. Several plans of the mines and works are given.

A detailed description of the means of transport at Bilbao has been published by M. Gandolfi,† an Italian engineer, who has brought up to date the tables published by Mr. W. Gill ‡ in 1882.

Sinking through Quicksand.—The Chapin Mining Company of Iron Mountain, Michigan, in sinking a shaft struck a bed of quicksand at a depth of 15 feet, and on boring, another and thicker bed was struck at a depth of 60 feet. The shaft is now being sunk through these quicksands, the Poetsch freezing arrangement having been adopted. Around a circle 29 feet in diameter, twenty-six 10-inch holes were bored to a depth of 101 feet. Into these holes 8-inch wrought-iron pipes were inserted, connected by wrought-iron couplings and securely plugged at the bottom. Inside of each of these large pipes is another, 1½ inch in diameter, which terminates at about 10 inches from the bottom. At the top each series of pipes is connected by tubing to two large tanks, which form a part of the freezing plant. A solution of calcium chloride is reduced by the freezing machine to a temperature of 25° C., and is then forced into the series of small pipes, and passing down these rises up through the larger outer pipes and returns to a store tank in the freezing-house. The wet ground is gradually frozen in circles around the pipes, and the circles, gradually increasing in diameter, join together and finally form a frozen mass, in which the shaft can be readily sunk. At the time to which the account refers the Iron Mountain shaft had reached a depth of 70 feet. An examina-

* *Mémoires de la Société des Ingénieurs Civils*, vol. xlii. pp. 199-280.

† This paper appears in the *Ingegneria Civile* of Turin, 1887, Nos. 9–12, and is translated in the *Revista Minera*, vol. xl., and in the *Revue Universelle des Mines*, vol. iv., Nos. 1 and 2.

‡ *Journal of the Iron and Steel Institute*, 1882, pp. 63-95.

tion made at this depth showed the ground to be frozen in a circle 45 feet in diameter.*

Rock Drills.—In a paper read by the Ritter von Rziha † before the Austrian Society of Engineers and Architects, the various kinds of rock-drills are discussed. The author gives a detailed list of treatises in which descriptions of the various kinds of rock-drills have appeared. A number of the best-known percussion machines are mentioned by the author, who observes that in Austria the Schram and the Ferroux drills are best known, whilst in Germany those of Frölich, Meyer, Jäger, and Schram are most frequently employed. The only important type of drills other than percussion ones is that of Brandt, which is just as frequently in use in Europe as is the percussion type, and hitherto both have been employed with almost equal success. In the Mansfeld district, both Brandt and Frölich drills have been employed for similar work, and for an equal amount of work done the cost has been about the same in both cases. The Brandt drills are preferable in cases where much water is met with, such as in sinking deep shafts and in cases where less power is available, since the power required for Brandt drills is only about $\frac{4}{7}$ths of that required for the Frölich percussion drill. Percussion drills are the most useful in long tunnels up to about 10,000 feet in length, where the compressed air escaping from the drill produces a sufficient ventilation. There are, the author states, four firms in Germany that undertake the driving of tunnels by rock-drills. They guarantee a progress of from 10 feet to 11½ feet a day in levels having a diameter of from 54 to 59 square feet, at a price of from £3, 10s. to £4, 12s. per foot, they providing the machinery; or at the rate of £1, 10s. to £2, 5s. if the necessary drills, &c., are found by the mine.

III.—*MECHANICAL PREPARATION.*

Concentration of Iron Ore at Norberg.—According to G. A. Granström,‡ the so-called "dry" ores of the Norberg district, Sweden, consist of several superimposed layers of red hæmatite, containing variable quantities of magnetite and quartz. Hand-picked the

* *Chicago Mining Review*, March 2, 1889.
† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxvii. pp. 50-53.
‡ *Jernkontorets Annaler*, vol. xxxiv. pp. 304-320.

ore contains, as a rule, less than 50 per cent. of iron, and from 20 to 30 per cent. of silica, and it usually requires the addition of about 40 per cent. of lime when smelted in a charcoal blast furnace. Experiments have therefore been made with a view to the mechanical concentration of the ore. In 1882 magnetic concentration was tried, but without success. The next experiments were made with a jigging machine having a variable stroke, and the results were to some extent successful. The fine enriched slimes were made into briquettes by the aid of lime and transported and smelted in this form. These briquettes yielded about 55 per cent. of iron, and gave a somewhat basic slag, intermediate between a bi- and a sesqui-silicate.

A Technical Commission was next appointed to examine into the subject, and they reported that there were no particular difficulties in the way of the concentration of the Norberg "dry" ores, and that it seemed desirable to lay down works for this purpose; still, they deemed it advisable to institute experiments on a larger scale before taking so decided a step. The works, they considered, should have a capacity of 300 tons a day, the cost of erection being about £18,400. They calculated that the cost of producing the ton of ore-lime briquettes would be about 8s. 11d., the ore costing in the first place 3s. 8d. per ton, the cost of concentration up to 60 per cent. of iron being 2s. 7½d. per ton, and the cost of converting into briquettes by the addition of 10 per cent. of burnt lime being 3d. per ton.

This estimate of the Commission led to the erection of an experimental works in 1885, the Government having granted a subvention of £1,660 for this purpose. These works were so arranged that the ore first passed through a stone-breaker, and thence through a conical trommel-screen about 5 feet in length, and varying in diameter from 34½ inches to 42½ inches. The perforations were 0·31 inch in diameter, and the trommel made twenty revolutions in the minute. The finer particles falling through these perforations passed direct to the classifying trommels, the larger pieces not separated in this manner being crushed by the aid of rolls. To each of the several sizes of ore from the classifying trommels a jigging machine was erected. The very finely divided ore was passed through a series of three small conical separators and thence to a large conical settling tank, 6 feet 7 inches in height, 7 feet 11 inches in width, and 13 feet 1½ inch in length. This tank was divided into two divisions. The jigging machines were seven in number, and were of the ordinary type.

In laying down this plant it was anticipated that about 17 tons of

mine fines would be treated daily. The erection was completed in August 1886 at a total cost of £2176. The plant started work on August 23, and was, with some few slight interruptions, continuously at work until December 18 of the same year. During this period there were produced in 191 shifts of 11½ hours each, 1119 tons of ore-slimes, 270 tons of intermediary products, and 658 tons of waste products, a production of 22½ tons in 24 hours. When finely-divided mine-stuff was being treated the average return of ore-slimes was 54·6 per cent. and of intermediary products 13·2, whilst when ore-fines were treated the percentages were respectively 63·0 and 11·7. The percentage of iron in the slimes varied from 53 to 63 per cent., of iron in the intermediary products from 38 to 53 per cent., and of iron in the residues from 16·7 to 26·3. The cost of concentration was as follows for the ton of slimes:—Wages, 2s. 11d.; steam-power, &c., 2s. 2d.; repairs, 1s. 3½d.; and analytical work, 8d.—a total of 7s. 0½d.

With regard to the phosphorus contained in the ore, analysis showed that this passed mostly into the enriched portion and not into the separated waste material. By very finely dividing the ore a larger percentage of the phosphorus was eliminated than would otherwise have been possible, but by treating the ore in this way a considerable loss of iron occurred.

The first of the following analyses shows the average composition of the enriched ore obtained during the year 1887, and the second analysis gives the results of a similar average sample of the enriched ore produced during the first half of 1888, but in the case of this latter sample all the larger ore sizes were eliminated before the sample was taken:—

Description.	Average Sample for 1887.	Average Sample for 1888.
	Per Cent.	Per Cent.
Ferric oxide	44·450	54·370
Magnetic oxide of iron	39·190	37·120
Manganous oxide	0·100	0·095
Magnesia	0·360	0·870
Lime	2·250	0·150
Alumina	1·150	2·710
Silica	13·310	5·080
Phosphoric anhydride	0·056	0·038
Sulphur	0·008	0·049
Totals	100·874	100·482

Eight to ten per cent. of lime was used in making the ore into briquettes. After having been stored for some time, these briquettes became so hard that they could be dropped on an iron plate from a height of several yards without undergoing fracture, and the great resistance of the briquettes to a crushing strain was shown by the aid of experiments made with a stone-breaker, the results of the experiments being given. The advantage of converting the ore into briquettes does not, however, appear to be proved.

The Buchanan Magnetic Rolls.—Mr. J. Birkenbine* describes the result of the use of the Buchanan magnetic rolls at the Croton Mines, New York. The ore is crushed, passed through a 15-mesh sieve, and then delivered to the Buchanan magnetic separator. This consists of iron rolls revolving on journals which are carried on insulated standards wound with copper wire. By connecting these wires with a battery, the standards become magnetic with opposite polarity and the rolls are charged thereby, making a magnetic field between the rolls. The ore being charged on the rolls, which revolve towards each other, is carried around the magnetic portion, adhering until it passes beyond the magnetic influence, whilst the non-magnetic particles drop between the rolls. The following table shows the results obtained when treating Croton (Theall) ore :—

Description.	Crude Ore.	Concentrates.	Tailings.
Iron	37·968	64·594	13·207
Silica	29·30	5.350	50·20
Phosphorus	0·383	0·050	0·492
Sulphur	0·522	1·253	0·924
Iron	31·28	62·56	4·66
Silica	35·50	6·825	58·05
Phosphorus	0·271	0·058	0·527
Sulphur	0·784	1·320	0·945

The Venström Magnetic Separator.—The Venström separator has been in use for over four years at Dannemora and at a number of other mines in Sweden, and has therefore passed the experimental stage. It differs from other magnetic separators in that it is capable

* *Journal of the United States Association of Charcoal Iron Workers*, vol. viii. pp. 107–109.

of taking ore in large sizes, so that it is possible to eliminate by concentration a good deal of waste rock without the expense of crushing it to a fine size. The machine has a stationary field magnet and an armature barrel consisting of a number of soft iron bars separated from one another by a non-magnetic material—in this case strips of wood. The whole is bound together by non-magnetic end rings. The bars are cut away alternately on the inside to make one bar project only toward the north poles of the magnet and the next only to the south poles. This gives each succeeding bar opposite magnetism. On each of the four sections of the magnet are wound 15 lbs. of copper wire. An Edison dynamo furnishes a current of 10 ampères and 35 volts. The ore is fed to the barrel by means of a hopper. The magnetic ore adheres to the bars of the barrel and is carried downward past the first delivery shoot. Below the machine the bars, departing from the influence of the electro-magnet, which is placed eccentrically, lose their power to hold the particles of magnetic iron ore, which then drop off. The particles of rock in the ore, being non-magnetic, drop off from the barrel almost immediately, and fall on the first shoot. It may be noted in passing that the dropping of ore on the barrel in the manner described, tends to lessen the power needed to make it rotate. It runs at a speed of about 30 revolutions, the power required being relatively small. The Venström machine is made in three sizes, the one used in New York having a diameter of barrel of 20 inches and a width of 15 inches. It is rated at a capacity of 3 tons per hour and will take ore up to $1\frac{1}{2}$ inch in size.

The machine is employed not only for separating magnetic iron ore, but also for converter cinder, mixed machine-tool filings, droppings from cupolas, spent foundry sand and for shot at blast furnaces. It has been employed for such uses at a number of places in Sweden.

The largest machine now in use in Sweden will handle anything that will go through a 3-inch mesh screen, and its output is stated to be 14 tons of clean ore per hour.*

The Edison Magnetic Ore Separator.—The principle on which this machine is based consists in deflecting the magnetic portions of the crushed iron ore by the aid of a powerful electro-magnet. The ore after being crushed and screened is delivered into a hopper, in the

* *Engineering and Mining Journal*, vol. xlvi. p. 437; *Journal of the United States Association of Charcoal Iron Workers*, vol. viii. pp. 105-107.

bottom of which is a long slit which can be closed by a sharp-edged casting, balanced by a counter-weight. Below this is the electro-magnet. This magnet is movable, and the strength of the current can be varied at will; in one instance a current varying from 25 to 30 ampéres at 110 volts is employed. An illustration of the machine appears in the *Iron Age*,* and the following results are given of some experimental trials :—

Description.		Crude Ore.	Concentrates.	Tailings.
New Bed Lean ore, Port Henry	Iron	53·20	69·90	7·67
	Phosphorus	0·03	0·01	0·08
Old Bed ore, Port Henry	Iron	59·5	69·15	7·10
	Phosphorus	1·77	0·41	11·06
Croton ore	Iron	37·97	64·72	11·04
	Phosphorus	0·38	0·10	0·97

IV.—*METALLURGICAL PREPARATION.*

Roasting Hudson River Carbonates.—The Hudson River carbonate ores are of two classes, Bessemer and non-Bessemer, existing in separate, though adjoining, beds. Both are carbonates, with small admixtures of oxides and other combinations. To prepare them for market they are roasted in kilns 60 feet in height. These have wrought-iron shells 24 feet in diameter, are lined with fire-brick, and supported by cast-iron mantle and columns. As originally built, the draught was wholly from the bottom; but afterward two rows of small circular holes were cut in them, a little short of half-way up, and encircling the kiln. The kilns are 10 in number, with an estimated daily roasting capacity of about 100 tons each.

The richer of the two classes of ore is a true Bessemer variety, containing only about 0·035 per cent. of phosphorus. It is uniform in character and not marked by any specially interesting features. In the present paper Mr. I. Olmsted † speaks mainly of the non-Bessemer ores. He furnishes two analyses that may serve to show the character of the two classes.

* Vol. xlii. p. 847.

† *Transactions of the American Institute of Mining Engineers*, vol. xvii.

Analyses of Roasted Ores.

	Bessemer. I.	Non-Bessemer. II.
Silica	9·20	17·18
Carbonic anhydride and water	0·55	undet.
Ferrous oxide	2·85	FeS_2, 1·47
Ferric oxide	63·03	65·73
Alumina	2·19	3·02
Lime	6·80	4·35
Magnesia	7·13	5·72
Oxide of manganese	3·90	2·66
Phosphoric anhydride	0·102	0·319
Sulphur	1·788	...
Oxygen with sulphur	1·58	...
	99·12	100·449
Metallic iron	46·34	46·70
Phosphorus	0·044	0·139
Sulphur	...	0·786

The ore always contains a considerable amount of water—sometimes, when it has been exposed to rain, as much as 8 per cent. The ore as drawn from the kilns presents a varied colour and form, which furnish but little guide to the eye in determining its nature and richness. The ores are usually magnetic after roasting. This magnetic property suggests the possibility of classifying the ore by an electrical separator, but the chief difficulty in the way appears to be the fine grain of the ore, and the intimate mixture of impurities, which would necessitate very fine crushing.

Examination shows four main characteristics in the roasted ore: (1) a rough, shapeless mass; (2) a fine-grained flat slate; (3) a mixture of white silica grains with red or black ore grains, occurring mainly in thick flat slabs; (4) so-called "clinkers." Nos. 1 and 4 are the richest. Class 4 presents the most interesting features. For some reason not yet clear, these clinkers form in the kilns, and require blasting. Too much heat has been the reason commonly assigned for this clinker formation; but that of itself would not produce the metallic iron visible in them. There must be some action of oxidising and reducing gases as the cause of the trouble. It might be promoted by the ore remaining longer in or near the fire than is necessary to completely roast it. This might easily happen, since the drawing of the kilns is regulated by the appearance of hot ore at the gates, the convenience of shipment, and other causes, not by the time necessary to roast. Clinkering might also arise from some of the ore fusing or reducing more easily than the rest, and thus running in the fire necessary to roast the more refractory.

In the non-Bessemer vein, there constantly occur seams of black slate, generally narrow. It is very siliceous, fine-grained, nearly black between the grey natural ore, breaks into thin plates, and furnishes Class 2. The fuel used is good culm, and the charge fixed by practice as best is about 1 ton of fuel to 30 of ore.

At certain times these clinkers form in large numbers and virtually scaffold the kiln, which decreases its output, and becomes hot throughout. Then they are termed "bad" clinkers, and are thrown out on account of the sulphur they contain. The average of this objectionable element in the ore, including clinkers, is from 0·70 to 0·90 per cent.; but the clinkers alone usually show over 2 per cent.

The author was once told that the ore would not make a large percentage of No. 1 or No. 2 iron, because of its manganese (2 to 4 per cent. of the black oxide) and sulphur; but since then he has seen a furnace, running on this non-Bessemer ore alone, making nothing but No. 1 iron for days together. In that iron, there was from 1·75 to 2·25 per cent. of manganese, and only a trace of sulphur. The iron, when raw, was covered with the cloud of sparks which ordinarily accompanies cold iron, and the slag had a chocolate-coloured or nearly black surface, yet contained only a trace of iron. The fumes at casting were remarkably dense and sulphurous, and he more than once noticed in them the odour of cyanides. The iron made exceptionally good castings, and pleased the foundrymen very much.

The variety in appearance and in composition of this non-Bessemer ore is very striking. This is well shown by the following experiment:—

A large sample of non-Bessemer ore was reduced to a coarse powder, divided into halves, and these marked respectively Nos. I. and II. No. I., without any further preparation, was passed over a 60-inch sieve, and the resulting powder marked A, the fine ore, tailings, &c., being marked B. No. II. and A and B were then carefully sampled and analysed, with the following results:—

	II.	A.	B.
Iron	39·06	44·51	37·70
Silica	23·95	18·40	27·00
Phosphorus	0·201	0·120	0·270

A partial repetition of the experiment, the analysis of II. being omitted, gave:—

	A.	B.
Iron	43·05	36·92
Silica	20·53	29·53
Phosphorus	0·102	0·183

The samples taken did not fairly represent the ore, being leaner than the average. If, as the author's experience goes to show, the soft ore is the richer, then the difference would have been more marked had the proper proportion of rich ore existed in the samples. The experiment has been well confirmed, and seems to show that the leaner, more siliceous, non-Bessemer ore really consists of a mixture of rich ore, with veins and lumps of lean, phosphatic material. There is no such difference visible in the natural ore, nor do the tests of diamond drill-cores and daily drill-samples from the mines encourage the belief. The author is, nevertheless, inclined to cling to the theory, and to consider the other disagreeable results to arise from the intimacy of the mixture, rendering a drill-core witness only as to the ore it actually contains.

REFRACTORY MATERIALS.

Durability of Ganister Bricks.—At the Glasgow Exhibition, samples of ganister brick were shown which had undergone the test of 2000 tons and upwards of steel being melted in front of them. One sample was a piece of brickwork taken from an open-hearth furnace that had been working at Middlesbrough for twelve months. It had run 462 casts and produced 6056 tons of steel without rebuilding.

Fire-bricks of Clay and Asbestos.—Beaurain-Vautherin * has patented a process for making fire-bricks by compressing in moulds an intimate mixture of 75 per cent. of asbestos and 25 per cent. of plastic refractory clay.

Limestone in Lower Silesia.—B. Kosmann † has analysed the limestone from the Mühlberg, near Kauffung, in Lower Silesia. The following are the results obtained, I. being the average composition, II. that of the pure white beds :—

	CaO.	MgO.	SiO_2.	Al_2O_3.	FeO.	MnO.	CO_2.	SO_3.	Totals.
I.	91·45	3·36	2·97	0·32	0·22	0·09	0·84	0·69	99·94
II.	96·70	0·61	0·89	0·42		...	0·72	0·64	99·98
III.	36·85	15·69	0·11	...	0·68	...	46·65	...	99·98
IV.	31·89	20·13	1·08	...	0·59	0·22	46·09	...	100·00

Analyses III. and IV. refer to the dolomitic limestones of Kunzendorf, near Landeck.

In the last volume of this Journal ‡ these analyses were quoted, and erroneously ascribed to Professor A. Orth.

* *Berg- und Hüttenmännische Zeitung*, vol. xlviii. p. 10.
† *Thonindustrie Zeitung*, vol. xii. pp. 406-407.
‡ No. II., 1888, p. 230.

FUEL.

CONTENTS.

	PAGE		PAGE
I. Calorific Value	250	V. Liquid Fuel	263
II. Coal	251	VI. Natural Gas	267
III. Charcoal	261	VII. Artificial Gas	270
IV. Coke	263	VIII. Coal-Mining	272

I.—*CALORIFIC VALUE.*

Determination of the Calorific Value of Coal.—Professor F. Schwackhöfer * discusses the merits of the following four methods of determining the calorific power of coal: (1) Berthier's reduction method; (2) the calculation of the calorific power from the elementary composition of the fuel; (3) the direct calorimetric method; and (4) the evaporation trials on a large scale. He concludes that only the theoretical calorific power formed by exact methods is of value. All other methods are of importance only for the particular plant in which the determination was made.

In the course of his paper, the author describes and illustrates the calorimeter he has designed, which he claims to exceed all others in accuracy.

A New Pyrometric Method.—Dr. Barus † has investigated the subject of the viscosity of gases up to 1000°, the temperature being measured by the combination of a porcelain air thermometer and a thermal junction of platinum and platinum-iridium. The observations suggest to the author a method of measuring high temperatures, which is based on Meyer's equation of gas transpiration. He gives a comparison of the temperatures thus measured with those obtained by a

* *Berg- und Hüttenmännische Zeitung*, vol. xlviii. pp. 4–6.
† *Annalen der Physik und Chemie*, vol. xxxvi. pp. 358–398.

irect method, and believes that greater precision can be obtained by ıis method than by any other. The paper is accompanied by diarams of the apparatus and of the curves that represent the results.

Pyrometer.—The pyrometer of MM. Mesuré and Nouel depends n the partial rotation of polarised light by a quartz plate. The rotaion varies with the intensity of the light; and as this can be measured, ıe temperature of the substance which emits the light can be deterıined. In the instrument a quartz plate is placed between the olarising and analysing prisms, the latter being turned till a definite eutral tint between green and red is produced. The angle is meaıred, and the corresponding temperature derived from a table.*

II.—*COAL.*

Analyses of Coal.—Bunte † gives the following typical analyses of oal, exclusive of water and ash :—

Description.	Carbon.	Hydrogen.	Oxygen, Nitrogen, Sulphur.
Westphalian gas coal	85·39	5·44	9·17
Silesian gas coal	84·30	5·30	9·90
Saar coal	84·54	5·43	10·12
Bohemian coal	82·65	5·88	11·47
Saxon coal	82·38	5·74	11·88

Coal-Mining in Spain.—In a paper describing the mining exhibits t the Barcelona International Exhibition, Mr. Bennett H. Brough ‡ ;ates that the Spanish coalfields cover an area of 3500 square miles, ıe quantity of available coal being estimated at 3500 million tons, of hich at least two-thirds can be mined with profit. Seeing that Spain roduces only half the coal it consumes, it is difficult to account for ıe inadequate prosecution of coal-mining in the kingdom. The outıt in 1885 did not exceed 919,440 tons, half of which amount was

* *Industries*, vol. vi. p. 331. See *Journal of the Iron and Steel Institute*, 1888, No. ., p. 194.
† *Journal für Gasbeleuchtung*, vol. xxxi. p. 861.
‡ *Colliery Guardian*, vol. lvi. p. 768.

raised in the coalfield of the Asturias, on the northern coast. The production and consumption of coal in Spain is clearly shown by the following official statistics:—

Year.	Coal.	Lignite.	Imports.	Consumption.
	Tons.	Tons.	Tons.	Tons.
1860	320,899	18,952	452,479	792,330
1870	621,832	40,095	566,911	1,228,838
1882	1,165,517	30,738	1,108,081	2,304,336
1885	919,440	26,464	1,067,837	2,013,741

Disregarding some small quantities of anthracite that occur in Silurian and Devonian strata in the Asturias, the coal deposits of Carboniferous age may be divided into four groups:—(1) The northern coalfield extending through the Asturias, Léon, and Palencia; (2) the central coalfield in the province of Cordova; (3) the southern coalfield in the province of Seville; and (4) the north-eastern coalfield in the provinces of Gerona and Lerida, on the southern flank of the Pyrenees. These coalfields, though geographically distinct, are undoubtedly of the same geological age. The important coalfield of the Asturias, from which in 1887 as much as 450,000 tons were raised, possesses fifty workable seams, varying in thickness from 16 inches to 6 feet, the coal being generally of excellent quality. The coal from this field was well shown at the Barcelona Exhibition, the finest exhibit being undoubtedly the collection of coal from the Marquis of Comillas' collieries at Aller. In addition to a well-arranged collection of coal samples and mine plans, the Marquis exhibited the produce of his collieries in a striking manner in the form of a lighthouse that was erected in the Exhibition grounds, built entirely of briquettes made from Aller coal. This coal, too, was again utilised in the construction of an effective trophy representing a double colliery roadway of the usual dimensions, surmounted by a mass of briquettes and three colliery tubs full of coal.

In a separate pavilion in the park the Andalusian Railway Company exhibited an interesting collection of samples of coal from their collieries at Belmez and Espiel, in Cordova, and from the information furnished by the director, Don Felix Brard, it is possible to give details of the actual condition of these important mines. The coal-measures in this field are deposited on Carboniferous limestone that rests unconformably on strata of Silurian age. The coalfield extends from north-east to south-west for a distance of 40 miles, and has

an average width of 1½ mile, the richest portions being situated between Espiel and Peñarroya, where mines have long been worked by several companies. The total area of the royalties worked by the Andalusian Railway Company amounts to 7413 acres. The seam worked by the group of the company's mines, including Santa Elisa, Ana, Pequeña, and Marcelino, is the richest in the coalfield. At the north-east its branches have a thickness of 50 feet, which increases to 260 feet towards the centre of the royalty, where it forms a lenticular mass. This group of mines is estimated to have in reserve six million tons of workable coal, exclusive of all coal at a greater depth than 500 yards. At Belmez four parallel seams are known; of these only two are wrought, at the Cabeza de Vaca Colliery. Assays of coals from this field gave the following results:—

	Fixed Carbon.	Ash.	Volatile Matter.
I. . . .	73·00	2·60	24·30
II. . . .	54·38	10·30	35·32
III. . . .	65·00	12·00	23·00

I. Santa Elisa. II. Cabeza de Vaca. III. Espiel. Complete analyses of coal from the Santa Elisa mine (IV.) and from the Cabeza de Vaca mine (V.) gave the following results:—

	Carbon.	Hydrogen.	Oxygen.	Sulphur.	Ash.
IV. . .	83·33	5·02	9·05	...	2·60
V. . .	73·15	4·72	8·33	1·50	12·30

From these analyses the calorific power is computed at 7967 calories for the Santa Elisa coal, and at 6384 calories for the Cabeza de Vaca coal. The briquettes made from Santa Elisa coal gave on experiment a calorific power of 7532 calories, whilst the coke made from the same coal has a calorific power of 7020 calories, and contains 10 per cent. of ash.

The Santa Elisa mine is the most important colliery in the Peninsula. It possesses a circular winding shaft, 13 feet in internal diameter, and 243 yards deep, lined throughout with masonry, and furnished with wooden guides; a circular ventilating shaft, 9 feet 10 inches in internal diameter, similar to the winding shaft; and a circular pumping shaft, 9 feet 10 inches in diameter, and 232 yards deep. Three other shafts have been sunk for working the branches of the main seam. They average 80 yards in depth. One of them is used for winding, and is furnished with a 28-horse-power engine, the second is used for pumping, and the third as a ladder-way for the colliers. Finally, there is another pumping shaft, 150 yards in depth. The main shaft is provided with iron pit

frames 40 feet in height. The cages are double-decked, and carry four trucks, each loaded with 992 lbs. of coal. Steel winding ropes are employed. The winding engine, made by Cockerill, of Seraing, has two cylinders, and is of the ordinary Belgian type. Its horse-power is 500. The engine-house also contains a horizontal 45-horse-power engine, used for driving a Guibal fan, 29 feet 6 inches in diameter, and 6 feet 6 inches wide, making fifty revolutions per minute, and in that time exhausting 21,200 cubic feet of air from the mine. The screens at the pit bank are reciprocating, and are driven by an 8-horse-power portable engine. There are four batteries of coke ovens, consisting in all of forty-four ovens, with a daily capacity of 50 tons. At the Cabeza de Vaca colliery the company have sunk a circular winding shaft 640 feet in depth, with metallic guides, and timbered throughout. The winding engine is horizontal, with a horse-power of 56. At this mine there is also a second winding shaft 830 feet deep, with a double cylinder 50-horse-power engine. There are two pumping shafts, and a ladder-way for the miners. At Vega del Fresno the company possesses repairing shops, and a manufactory of patent fuel capable of producing 30,000 tons annually. Attached to these works is a coal-washing plant equipped with a 12-horse-power portable engine. It treats 80 tons per day. The engine for the patent fuel works has a horse-power of 40; it drives a pitch-grinding mill, various elevators, a Carr disintegrator, and the presses for moulding the briquettes, each of the latter weighing about 9 lbs. A branch of the Cordova railway unites the Santa Elisa colliery with that of the Cabeza de Vaca, and with the works at Vega del Fresno. The Santa Elisa colliery produces from 500 to 600 tons of coal daily, or 180,000 to 200,000 tons annually. The Cabeza de Vaca colliery is capable of producing 80,000 tons annually. The present output, however, is limited to the amount of coal sold, a quantity varying from 105,000 to 110,000 tons. Previous to August 1, 1882, when these mines were taken over by the company, the death-rate was terribly high. Accidents, such as that of April 1, 1868, when thirty-eight colliers were killed, were of frequent occurrence. Happily, the precautions recently taken have obviated the recurrence of such disasters. Naked lights are now forbidden to be used, and the Davy has been superseded by the Marsaut lamp, and by the Breguet stationary electric light. The total number of workmen employed by the company is 1065. This includes, at the Santa Elisa mine, 420 underground, 110 at surface, and 25 at the coke ovens; at the Cabeza de Vaca, 310 underground, and 70 at surface; and at

Vega del Fresno, 65 at the patent-fuel works, 35 carpenters and smiths, and 15 on the railway, together with an executive staff of 15.

Among the other exhibits of coal at Barcelona, good samples were shown from Orbó and Barruelo in the province of Palencia, from Quiros in that of Oviedo, from Sabero in that of Léon, and from San Juan de las Abadesas in Upper Catalonia. The coal deposit at the last-named locality has a length of 10 miles, and a width of 1½ mile. It is deposited on Carboniferous limestone, and is covered by sandstones of Permian or Triassic age. The general course of the seams is from east to west. In places, however, the seams are greatly twisted and contorted by the intrusion of porphyry and melaphyre. The railway from Granollers to San Juan de las Abadesas has opened a new era for this coal region, which for years past has had to contend with economic difficulties. The general, though not unbroken, connection of this coalfield with the important coalfields of the Asturias has been clearly shown by Professor Lebour.*

Lignite, or brown-coal, occurs in thirty of the provinces of the Peninsula, the principal deposits being the Cretaceous lignite of Berga, and the Tertiary lignites of Calaf in the province of Barcelona, and of Balcoy in Alicante, the Upper Cretaceous lignites of Hernani, Aya, and Cestona in Guipuzcoa, the Jurassic lignite of Prejano in Logroño, the Cretaceous lignite of Las Rosas in Santander; and, lastly, the Lower Cretaceous coal deposits of Teruel, which is of such richness that it may be regarded as the most important lignite deposit in Spain.

Coal-Mining in Servia.—A. Götting † states that the coalfield of Servia, which lies in the immediate neighbourhood of the Bulgarian border, has recently been energetically exploited. The collieries occur in the Timok Valley, near the town of Zaječar, and are connected with the lower Danube by a railway 50 miles in length, as, owing to political difficulties, the much shorter route *viâ* Widdin was impossible. The coal is found in the horizon of the Upper Lias. The beds are greatly inclined, and faults are frequent. The coal is found between Senon, on the hanging-wall, and sandstone on the foot-wall. Hitherto only one bed has been worked, and this has an average thickness of 20 feet, the maximum thickness being about as much again. The coal is usually covered with about 7 feet of earth. The proved quantity of coal is about 850,000 tons. The coal is not of a coking

* *Journal of the Iron and Steel Institute*, 1887, p. 346.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxvi. p. 664.

variety, and falls readily in pieces, but it is largely manufactured into briquettes.

The Coalfields of Madagascar.—It was at one time believed that the Bavatobé coalfield, Madagascar, was exceedingly rich. This opinion proves, however, to have been fallacious. Messrs. Rigaud and Guinard* made, in 1888, an examination of the north-east coast of Madagascar, and in their report they point out that the carboniferous region is divided into three main sections: (1) *Permian,* containing no coal at all; (2) *Carboniferous,* about eighteen miles in length, along the coast, containing numerous seams of coal varying in thickness from $\frac{3}{4}$ to $3\frac{1}{4}$ inches; (3) another *Permian* division, also absolutely sterile as regards coal.

In conclusion the report states that the Bavatobé coalfield is not only much smaller than was previously supposed, but is also extremely poor in coal, there being no large deposit of coal in the whole field, as far as has yet been ascertained.

Coal in South Africa.—According to A. Schenk,† horizontal seams of coal occur in the so-called Stromberg beds of the Karroo formation, at various places in Cape Colony, in the region east of the Drakensberg, at Newcastle and Dundee in Natal, and at several localities in the Transvaal and in the Orange Free State. Anthracitic coal occurs on the Buffelskloof farm in the Camdeboo Mountains, traversing the Katroo schist and sandstones. It is highly probable that this coal is due to the decomposition of carburetted gases, which possibly emanate from the Ecca shales situated below. In the diamond-fields, where these shales are being sunk through, explosive gases are frequently met with.

Coal in New South Wales.—According to Mr. H. Wood,‡ the measures of New South Wales embrace an area of 23,950 square miles. The seams worked vary from 3 to 25 feet in thickness; they are nearly horizontal, and in some localities are considerably above sea-level. At the present time there are 41 collieries at work, affording employment to 4125 miners. In a report by Mr. J. Mackenzie, descriptive diagrams

* *Génie Civil*, vol. xiv. p. 248, with map.

† *Zeitschrift der Deutschen Geologischen Gesellschaft*, vol. xl. p. 595.

‡ Department of Mines, Sydney. Mineral Products of New South Wales, by H. Wood; Notes on the Geology of New South Wales, by C. S. Wilkinson; and Description of the Seams of Coal worked in New South Wales, by J. Mackenzie.

ure given of the different seams hitherto opened, and Mr. H. Wood reprints a report by Mr. W. A. Dixon upon the analysis of coals from the principal coalfields of the world, which come, or may come, into competition with the coals of the colony. The analyses of foreign coals collated number 198, and those of the coals of New South Wales 44. The report is accompanied by twenty-two large folding plates of maps and plans.

Coal Discoveries in South Australia.—Carbonaceous shale has been found at Leigh Creek, and the Government geologist has reported a discovery of coal near Kuntha Hill, 120 miles from Hergott. The prospects are so encouraging that additional searches will be made by boring or sinking shafts.*

The Coal Deposits of the Tennessee Valley.—The coalfield lying to the east of the Cincinnati, New Orleans, and Texas Pacific Railway is of large extent. It contains several mountain ranges, a height of over 3200 feet above sea-level being attained at several places. The coal found is largely used in the manufacture of coke for blast furnace use. A number of coal and iron mines and works situated at this coalfield are described in the *Iron Age*. †

Coal in Alaska.—A careful exploration has recently been made of the Copper River district, and it is stated that very large deposits of coal have been found in the neighbourhood of Four Rivers.‡

Coal Mining in Kentucky.—The fifth annual report of the Inspector of Mines for Kentucky gives information of the various railway extensions, especially those reaching into the coal districts of the State. It shows that coal-mining has largely increased as compared with previous years, and that the condition of the mines is more satisfactory and safer. Various devices for labour-saving are illustrated, as well as the designs for ventilation and handling the coal after it comes to the surface. A careful description of all the works in the State is given, and various comparative tables, showing the high value of certain coals for steam and other purposes. The great lack so far is good coking coal, but this, it is said, will be completely overcome by the opening

* *British Trade Journal*, vol. xxvii. No. 317.
† Vol. xliii. p. 7.
‡ *The Juneau Mining Record*, September 20, 1888.

up of the deposits in the Cumberland Gap region; but whether this coke can be carried to the furnaces in Tennessee and Alabama at a profit to the ovens, and cheap enough for the consumers, remains to be proved. In the year 1887 Kentucky produced only about 2,000,000 tons of coal, Illinois 10,000,000, Ohio 11,000,000, and Pennsylvania 30,000,000, and yet it is asserted that Kentucky has a larger coal area than the great coal State, showing, if this is a fact, that coal-mining is still in its infancy there. The cannel coal of Kentucky is widely known for its gas-producing qualities, and in certain sections of the State it lies so as to be easily and profitably worked.

In the survey of Kentucky under Mr. J. R. Proctor, several reports have recently been issued. Amongst these is a chemical report by Dr. R. Peter, containing a large number of analyses of the coals and petroleum of the State. Mr. Proctor states that in addition to the coal beneath the conglomerate at the base of the coal-measures, there is above it, north of Pine Mountain, 1650 feet of coal-measures, containing nine beds of workable thickness, and between the Pine and Cumberland Mountains a still greater thickness with twelve or more beds.

Coal Deposits of the South Appalachian Field.—In a report by Mr. J. R. Proctor, State Geologist of Kentucky, it is stated that immediately to the north of Big Stone Gap there are several thick beds of coal. Some of the coal from these deposits is of a good caking character; cannel, splint, and good gas coals also occur. Iron ores, suitable for steel-making, occur in the immediate neighbourhood of the coal.

Coal Deposits of the Southern United States.—For a distance of 91 miles, commencing at a point 1 mile south of the Cumberland River, the Cincinnati, New Orleans, and Texas Pacific Railway is built on coal-bearing strata, and for a further distance of 72 miles is never at a greater distance from such strata than 1 mile, and a less distance from a deposit of iron ore. For another 198 miles, coal seams and iron ore deposits are met with at a distance of from 1 to 2 miles. From Emory Gap to Drayton, a distance of 41 miles, there is a continuous vein of iron ore, from 3 to 5 feet in thickness, which has been proved to a depth of 225 feet. For nearly 198 miles a continuous vein of iron ore, frequently 20 to 25 feet in thickness, adjoins the Alabama Great Southern Railway; coal, too, is near, but not so close as it is at the places mentioned above.

The coal-bearing strata, commencing at the Cumberland River, are "sub-conglomerate" beds, the coal being found in the shales and sandstones between the greatest and the lowest conglomerate and the limestone. The Tennessee coalfield has, however, never been thoroughly surveyed. A number of the collieries are described.*

German Lignite.—The beds of lignite in Saxony and on both banks of the Rhine near Cologne are from 10 to 20 yards thick and are covered with 5 to 10 yards of gravel.† The lignite is of a dark chocolate colour, and is about as soft as cheese, so that it is worked by the pick and shovel, no explosives being required. Generally the material is got by open-work quarries, though in some cases, as at Honem near Cologne, the method of work used is similar to the pillar and stall, by which means about two-thirds is extracted.

The average moisture of the raw material is about 50 per cent., and this is reduced to about 18 per cent. for the proper manufacture of briquettes. The following table shows the relative values of the finished products, which are simply the dried and compressed lignite without extraneous matter :—

Samples.	Moisture.	Ash.	Calories.
1	18·66	4·9	4235·0
2	17·6	6·2	3954·6
3	13·6	5·4	4352·4
4	14·6	5·4	4186·0

The raw material is delivered from the working face to the factories at 7d. per ton by wire rope tramways. It is then crushed, ground, and dried on trays in ovens by exhaust steam. The dried material is then automatically fed and compressed into briquettes by a reciprocating plunger. The natural resin in the lignite forms the cementing material as it is softened by the heat generated in the compression of the briquettes. The presses are water-cooled to prevent too high a temperature. Each press turns out 70 briquettes per minute, or 30 tons per day, and is supplied by two ovens, each drying 18 tons of the raw material daily. Cost of working and other particulars are given.

* *Iron Age*, vol. xlii. p. 890.
† *Engineering*, vol. xlvii. p. 271–273.

New Fossil Resins from the Coal-Measures.—Mr. W. Ivison Macadam * has examined some brown layers in the coals in the neighbourhood of Methil and Kilmarnock. In the former district these resins are found in large quantities in the so-called Chemise coal, a seam which, although not the thickest in the coal-measures of Fife, is probably the most valuable in the series.

The portion of resinous products soluble in ether gave volatile products when heated to 100° C. The results of the analyses were as follows:—

Description.	Kilmarnock Coal.		Methil Coal.	
	Soluble in Ether.	Soluble in Chloroform.	Soluble in Ether.	Soluble in Chloroform.
Carbon	84·275	74·281	57·497	66·700
Hydrogen . . .	9·361	6·515	7·527	7·315
Oxygen	6·364	19·204	34·976	25·985

Utilisation of Refuse Fuel.—In describing the mining and metallurgical exhibits in the Barcelona International Exhibition, Mr. Bennett H. Brough † states that in the French section Mr. G. A. Godillot showed a new type of furnace for heating boilers, specially adapted for burning refuse materials hitherto considered worthless. The fuel is supplied through a hopper on the top of the furnace, and is conducted by means of an endless screw to the apex of a grate in the shape of a half cone. The supply of fuel can easily be regulated. During its gradual passage down the cone the fuel is dried, heated, and burned. It finally reaches the horizontal grate, which has the shape of a horse-shoe, and here the combustion is completed, the ashes being easily withdrawn. Excellent results have been obtained with such fuels as tan-yard refuse containing 68 per cent. of moisture, chips from dye-works with 60 per cent. of moisture, and dried sawdust and shavings.

* *Chemical News*, vol. lix. pp. 1, 2.

† *Journal of the Society of Arts*, vol. xxxvi. p. 1160.

III.—*CHARCOAL.*

Proportion of Ash and Phosphorus in Charcoal.—As the superiority of Swedish irons depends largely on the small amount of phosphorus they contain, it has become a source of alarm to find that pig iron made of very pure ore often contains more phosphorus than the composition of the charge warrants. This excess of phosphorus is necessarily derived from the charcoal used in the furnace. Elaborate investigations into the matter have been undertaken by R. Åkerman and C. G. Särnström,* who have published an exhaustive report on the subject.

The method of charring, they show, has no influence on the amount of phosphorus in charcoal. For charring and incinerating without the risk of losing ash, the authors found it most convenient to use sheet iron dishes 8 inches in diameter, with lids having a diameter of 11 inches. The latter rested, convex part upwards, on two wires placed across the dishes. The final combustion was made in platinum crucibles. The samples of wood examined consisted of cubes that were kept for a month at a temperature of 68° F. before being weighed. For charring and incinerating about 1000 grammes of the cubes and 500 grammes of the bark were generally used.

In a series of thirteen tables of analytical results, the authors show the influence of the species of wood on the amounts of ash and phosphorus, and the different ash and phosphorus percentages in different parts of the trees. The following are the principal conclusions arrived at:—

Birch, alder, and ash contain four to five times as much phosphorus as fir and pine. Of the latter, fir has more ash than pine, but scarcely as much phosphorus. Of two samples of the same species of wood, taken from different places, one may contain twice as much phosphorus as the other. The wood of the fir when cut in the winter contains more phosphorus than when cut in the spring or summer. Bark from the fir or pine contains from twelve to fifteen times more phosphorus than the wood. Branches from all the trees examined contain considerably more phosphorus than wood from the tree proper. The surface wood of the fir and pine contains many times more phosphorus than the central wood, whilst the amounts of ash are the same in both.

* *Jernkontorets Annaler*, vol. xliii. pp. 261–304. An abstract of this paper is given in the *Journal of the United States Association of Charcoal Iron Workers*, vol. viii. pp. 81–97.

The amount of phosphorus is materially reduced by soaking the surface wood.

The Pierce Charcoal Process.—In a paper recently contributed to the American Association for the Advancement of Science, Professor O. H. Landreth describes the Pierce charcoal process. This process is now in operation at nine works, the aggregate annual capacity of which is 325,000 cords of wood. The process consists in charring the wood in circular, flat-topped brick kilns, with condensation of the products of the dry distillation, the heat for the operation being obtained by the combustion of the waste gas or other fuel in a separate fireplace placed below the kiln. The charring is completed and the kiln is discharged in eighteen days. The following table shows the nature and quantity of the products obtained in this process. One cord of dry wood yields:—

Products.	Yield in Gallons.	Yield per Cent.
Methylic alcohol . . .	4·4	0.75
Acetic acid	4·6	1·00
Tar	16·5	4·00
Water	220·7	45·95
Gas	11,000 cubic feet	23·00
Charcoal	50·6 bushels.	25·30

The charcoal produced from Tennessee wood by this process weighs on the average 20 lbs. to the bushel, whilst that made by the ordinary methods only weighs about 16 lbs. to the bushel, and it is therefore better adapted for use in ironworks. A 60-ton blast furnace requires in Tennessee about 5000 bushels of charcoal daily, or the output of two Pierce kilns. Allowing one-sixth of the total number of kilns as undergoing repairs, the total number of kilns required for a blast furnace of the above size would be forty-two.

The World's Consumption of Charcoal.—According to Professor Winkler,* the world's production of charcoal amounts to 360 million tons annually, a quantity of charcoal equal in heating power to 1640 million cubic yards of newly-felled pinewood. For this 2600 million pine trees, eighty years old, must have been cut, and must have occupied

* *Dingler's polytechnisches Journal*, vol. cclxx. p. 336.

an area of 10,400 square miles. In a forest worked systematically, for this an area of 812,000 square miles would be necessary, an area four times that of the German Empire.

IV.—*COKE.*

Heating Coke Ovens by Natural Gas.—The use of natural gas for the purpose of heating coke ovens has, it is stated, been attended with success. According to the *Pittsburgh Times* the use of the gas affords considerable economy in the heating up of cold ovens. It has been adopted by a number of companies in the Connellsville coke district.

The Adams Coke-Oven Bottom.—A number of experimental coke-ovens have been erected by the Adams Coke-Bottom Manufacturing Company at Mansfield, United States. The ovens are constructed with a false bottom, which is worked by hydraulic pressure. It is claimed that by this means one man is able to draw 25 ovens a day as compared with 3 or 4 ovens by the ordinary methods. Another advantage is that the ovens are not cooled when the draw is made; a new bottom can be immediately put in, and four drawings can be made instead of three, as at present.*

A Coke Screening-Machine.—The Schoonmaker Coke Company of Pittsburgh, Pennsylvania, have recently erected a new coke-crushing machine, in which the coke, instead of passing through a revolving shaft, as is the case with the coke-crushers now in use, will pass over a number of screens so arranged that the different sizes fall into bins ready for shipment entirely free from dust.†

V.—*LIQUID FUEL.*

Genesis of Petroleum.—The solid matter present in mineral oils has recently been examined by J. A. Le Bel,‡ who has established the fact that asphalt obtained from petroleum contains a large percentage of inorganic constituents. Ash from asphalt derived from Egyptian mineral oil contained 11 per cent. of lime and sulphur, that from

* *Iron Age*, vol. xliii. p. 319.
† *Engineering and Mining Journal*, vol. xlvi. p. 307.
‡ *Industries*, vol. vi. p. 356.

Crimean oils yielded 6 per cent. Asphalt from Lobsann in Alsatia gave 5·4 per cent. of ash, containing lime, iron, silica, sulphuric acid, and a trace of manganese. The presence of silica is considered by the author to support the theory of Mendeleeff, that mineral oils are formed by the action of steam on heated rocks in the interior of the earth.

The Petroleum of Galicia.—According to L. Babu,* in the district of Sloboda, which is the most important in the Carpathians, petroleum occurs impregnating the sandstone. There are a large number of wells, which in most cases have been bored by the Canadian system, which possesses the advantages of rapidity and cheapness. The oil is extracted by means of pumps. The character of the oil is extremely variable. It is sometimes brown and sometimes green, and contains 1 to 6 per cent. of paraffin. The crude oil is refined at works in the neighbourhood. The total production of Sloboda may be estimated at 2000 barrels per 24 hours.

In the vicinity of numerous deposits of petroleum, ozokerite, a solid hydrocarbon, occurs at Boryslaw in veins and beds in the Miocene clays and sandstones. It is difficult to form an idea of the importance of the industry. There are, extended over 220 to 250 acres, some thousands of shafts, of which about one-tenth are at work. The mineral is worked by means of shafts and levels. The former are a yard square, and are not more than 3 to 10 yards apart, and descend to a depth of 400 feet. The dryness of the ground facilitates the working. On the other hand, on account of the presence of explosive gases, the ventilation is of the utmost importance. In most cases a fan is placed at the bottom of the shaft, and safety lamps are employed. When raised from the mine, the ozokerite is hand-picked, washed in cold water, then in hot water, and finally treated with benzine and with steam. Before being placed on the market, the ozokerite is cast into masses weighing about 120 lbs., which are sold at £12 to £14 per ton. The annual production of Boryslaw represents a value of £200,000.

Mr. R. N. Boyd † gives a short history of oil production in Galicia, and describes the various forms of boring rig used to make the wells. At first shafts were sunk and the oil drawn up in buckets. Hand-bored wells were next used, and now various forms of Canadian and American rigs are used. The diamond drill has also been employed.

Small pumps with strokes of 10 or 12 inches and barrels 1 to 1½

* *Annales des Mines*, vol. xiv. pp. 162–196.

† Paper read before the Society of Civil and Mechanical Engineers, January 23, 1889.

inch in diameter are used to raise the oil; they are connected to the pumping engine, which serves any number of wells up to 500 feet distance. Each pump is hitched on daily as long as the oil lasts.

The density of the oil varies from 0·750 to 0·950, averaging from 0·8 to 0·85. In 1874 the production was 150,000 barrels, and this rose to 800,000 barrels in 1887.

Petroleum in Venezuela.—Mr. Plumacher,* United States Consul at Maracaibo, reports that part of the district of Colon is very rich in asphalt and petroleum. One spring is said to yield over 5000 gallons daily of excellent quality and with a density of 83 degrees. Deposits of coal, asphalt, and petroleum are also found in the state of Zulia.

The Use of Petroleum in Boiler Furnaces.—A battery of 14 boilers at the South Chicago works of the North Chicago Rolling Mill Company has been converted to admit of the use of petroleum as fuel in the place of coal. It has been found that 151 gallons of oil did the same amount of work as 1 ton of Indiana lump coal. The first cost of the oil is slightly less than that of the coal, but the saving in labour effected by the use of oil is very great, 4 men working the boilers when oil is used, as compared with 25 men when coal was employed. There is much less wear and tear in the case of oil; no smoke, ashes, nor dust; and the general efficiency of the battery of boilers is greatly increased.†

Liquid Fuel in the Manufacture of Iron.—Mr. E. A. Brayley Hodgetts ‡ describes the general application of liquid fuel for heating purposes, and especially for iron re-heating furnaces. The fuel may be burnt as a liquid, as a gas, or in the form of spray. The latter method is most economical, especially when the spray is produced by compressed air and not by steam. Special mention is made of Urquhart's and of d'Allest's burners.

The oil-furnace at Woolwich, if started cold, will heat a 6-inch armour-plate within two and a half hours after starting, instead of about ten hours with the coal furnace. The plate is also remarkably free from scale, and its quality is not affected. The Eames process, in which a steam boiler is combined with a re-heating furnace, is also men-

* *Engineer*, vol. lxvii. p. 9.

† *Iron Age*, vol. xlii. p. 736.

‡ Paper read before the Society of Civil and Mechanical Engineers, March 6, 1889.

tioned. Professor Wurtz describes one of these furnaces working off seven charges, averaging 2500 lbs. of rolled iron per day of ten hours, with a consumption of 200 lbs. or 30 gallons of oil per hour.

Petroleum Refuse as Fuel.—Mr. T. Urquhart* describes the method adopted at the Borisoglebsk works of the Grazi and Tsaritsin Railway, for utilising petroleum refuse as fuel in scrap-welding furnaces. Two furnaces, a large and a smaller one, are placed side by side. They are both of the usual reverberatory form, but in place of the fire-grate have the spray-injectors for supplying the liquid fuel. A tank containing the petroleum refuse is placed on top of the larger furnace, so that its contents may be kept liquid, during the cold season, by the heat radiating from the furnace. From this tank a main supply pipe, fitted with a stop-cock, is taken to each furnace. These main tubes terminate in three vertical branch pipes, fitted with taps for regulating the flow of the petroleum. From these taps the petroleum drops on to an inclined shoot, forming the top part of the spray-injector. This consists of a flat tuyere, of rectangular section, with the above-mentioned shoot on top of it, cast in one piece. The petroleum from the branch pipes flows down the shoot, and as it passes over the lower edge is met by the blast issuing from the tuyere, and projected in the form of spray against the hot fire-bridge and converted into vapour, which then ignites. The relative proportions of petroleum and air can be regulated so exactly that a perfect welding heat can be maintained in the furnace without any smoke being emitted. Three spray-injectors are required for the larger furnace, and two for the smaller one. Since there is no unconsumed fuel or solid residues left, no ash-pit is required, and the furnace can be worked continuously until repairs to the roof or bed necessitate a stoppage. The furnace slags very freely, showing that a proper temperature is maintained. Cold-blast is used, which is taken from the mains supplying the ordinary smithy fires. The waste heat from both furnaces is used under a large elephant boiler supplying steam for the hammers and rolling mill.

The great simplicity of the appliances for utilising liquid fuel in metallurgical work, even for forgings of the largest size, and the absence of sulphur and other elements exercising a deleterious influence on iron, commend its use in all localities where it can be obtained at cheap rates. Tests made on iron rolled from poor unwashed scrap welded with liquid fuel, show that a homogeneous ductile metal of high quality is invari-

* *Proceedings of the Institution of Mechanical Engineers*, 1889, pp. 36–84.

ably produced. Compared with coal a saving of 40 per cent. in weight is effected, besides the output being considerably increased. In the larger furnace 17 cwts. of petroleum refuse are required to each ton of blooms, three times welded from small unwashed scrap. The usual loss of iron is from about 18 to 20 per cent. By working both furnaces together, passing the blooms from one to the other to obviate loss of heat in them and in the furnaces, the consumption of fuel has been reduced to 13 cwts. per ton of rolled bars of light sections. On Monday mornings 3½ hours and a consumption of 540 lbs. of fuel are required to get up a welding heat, on other days 1¾ hour and 125 lbs. of fuel are sufficient. The author also uses the same spray injectors in four tyre-heating furnaces. The calorific value of petroleum is stated by the author to be 19,832 thermal units, as compared with 14,112 thermal units for good English coal, the latter being the mean of ninety-eight samples.

Oil-fired Forge.—In Mr. B. H. Thwaites' furnace* the oil is allowed to flow by gravity, or is introduced by a steam jet into the furnace through a spiral retort, wherein the oil is converted into gas. The air for combustion is heated to as much as 500° F. in a tubular recuperator. In an experiment made with the oil flowing in by gravity, welding heat was reached in forty-five minutes, with an expenditure of 7·88 lbs. of oil per cwt. of metal, giving a useful thermic efficiency of 27·9 per cent. When the oil was injected by steam, together with a certain amount of air, sixteen minutes only was required, and only 3·507 lbs. of oil was used, thus giving an efficiency of 51·7 per cent.

VI.—*NATURAL GAS.*

Natural Gas in China.—Mr. Denby, United States Consul at Pekin, describes the method of boring wells for brine, and states that petroleum is struck at a depth of 1800 to 2000 feet. At that depth gas escapes, when the hole is capped by a wooden cap, and the gas is led off to the brine evaporation pans.

Natural Gas in Indiana.—The natural gas district of Indiana, United States, lies to the north-west of Indianapolis, at a distance of about ten miles from that city. The district comprises an area about

* *Industries*, vol. vi. pp. 220–221.

sixty miles in length and forty miles in width; it is the largest yet discovered. The discovery of natural gas in Indiana was made about two years ago, since when numerous wells have been sunk, the average depth being rather more than 900 feet. The chief centres of the gas district are the county towns of Kohomo, Marion, Anderson, and Muncie, the population of each of which has doubled since the discovery of the gas.*

Natural Gas in Meade County, Kentucky.—Professor Edward Orton, the State Geologist of Ohio, has submitted to the State Geologist of Kentucky a report on the natural gas district in the neighbourhood of Louisville, the centre of the district being at a distance of 27 miles from that city. A pipe line 30 miles in length connects Louisville with the gas wells. In sinking the wells from 100 to 125 feet of clay and gravel is first met with; then follows a series of limestones, shales, and shaly sandstones varying in thickness from 100 to 300 feet; this, in turn, is followed by about 100 feet of soft blue shale, termed soapstone. In the upper beds of this soapstone the casing of the wells is usually set. The soapstone is underlain by a bed of black shale 50 to 100 feet in thickness, and this is the main gas rock, and also the source of the salt springs of this district.

The gas produced from the Ohio shales is of the Pennsylvanian type, free from the sulphurous compound occurring in the gas obtained from limestone beds. The gas occurs at a low pressure, which never exceeds 100 lbs. to the square inch, and is usually from 10 to 30 lbs. The daily yield is consequently relatively small, a production of about 100,000 cubic feet a day being common. The gas is not driven by a salt-water column, nor are the wells much improved by the use of torpedoes. The gas of the shale wells appears to be indigenous—that is to say, to be derived from the shale itself, the supply being possibly maintained by a slow conversion of the oil, with which the shale is charged, into gas.

The Meade County gas, on the other hand, is high pressure gas; it is associated with and driven by a salt-water column. The wells reach a maximum capacity of 2,000,000 cubic feet a day. They are greatly improved by the use of torpedoes. At the centre of the new field the gas pressure ranges from 100 to 125 lbs. to the square inch, the depth of the wells from the surface varying from 300 to 500 feet.

The whole of the differences enumerated above appear to depend on the relative porosity of the shale in which the gas occurs.

* *Iron Age*, vol. xlii. pp. 940, 975.

The total daily production of four gas wells belonging to the Union Gas Company exceeds 3,000,000 cubic feet. Bickerstaff No. 2 well yields upwards of 2,000,000 cubic feet a day. In the case of this latter well the shale was struck at a depth of 342 feet, and gas in large volume at 368 feet. The well was torpedoed with 45 lbs. of 75 per cent. dynamite, and the flow of gas was greatly increased. The gas is perfectly dry.

The Moreman, one of the wells examined by the author of the report, has been steadily yielding gas since the year 1863. Its present yield is 2,000,000 cubic feet a day. It is probable that the yield was formerly much greater, but even assuming the present to be the average daily yield for the whole period of its existence, calculation shows it to have afforded the enormous quantity of 1,825,000,000 cubic feet of gas, the value of which, taken at an average price of 5d. per 1000 cubic feet, amounts to about £40,000. The extreme vitality of this well is a favourable indication as to the permanent value of the field.

Natural Gas in Iron Making.—The prominence which natural gas has recently attained as a fuel in the manufacture of iron and steel in the United States naturally directs attention to its relation to other kinds of fuel which are used in this industry. According to Mr. J. M. Swank* the development of natural gas in the United States as a fuel in the manufacture of the finished forms of iron and steel dates from 1874. It is scarcely necessary to say that natural gas is not used in the manufacture of pig iron. In each instance the gas used was obtained from wells that were sunk for oil, but were found to produce only gas. In 1883 the substitution of natural gas for bituminous coal in rolling mills and steelworks received much attention at Pittsburgh, owing to the discovery of natural gas in large quantities at the neighbouring town of Murrysville; but as late as September 1884 there were in all only six rolling mills and steel works in the United States which were using the new fuel. During the next two years the use of natural gas in the manufacture of iron and steel made rapid progress. In August 1886 there were sixty-eight rolling mills and steelworks which used the new fuel. During the next fifteen months still further progress was made. In November 1887 there were ninety-six rolling mills and steelworks which wholly, or in part, used natural gas as fuel, and over one hundred are now

* Mineral Resources of the United States, 1888, p. 24.

using it. The whole number of rolling mills and steelworks in the United States in November 1887, completed or in course of erection, was 445, of which, as will be seen from the above figures, nearly one fourth used natural gas as fuel. Natural gas not having been found in the anthracite coal region or its vicinity, its use has not interfered with that of anthracite coal in rolling mills and steelworks, but wherever it is used it displaces bituminous coal. It displaces no other fuel.

The possession of natural gas, desirable and valuable as it is, does not insure any of the localities which use it in the manufacture of iron and steel against the sharp competition of other localities which do not have it, but which possess other advantages, as, for instance, proximity to markets of large consumption. Moreover, natural gas has a rival as a cheap and cleanly fuel in water-oil gas produced from petroleum, which is steadily growing in popularity among iron and steel manufacturers. It is claimed that this fuel is cheaper than coal, or than gas made from it, and that it possesses all the desirable qualities of natural gas, and is far safer. This new fuel possesses also the advantage that it can be produced and used where natural gas cannot be obtained, and even where the cost of coal may be too expensive to justify the use of the latter fuel.

VII.—*ARTIFICIAL GAS.*

Ingham Gas Producer.—This producer is circular and cased with iron; the fuel chamber is circular in plan and conical vertically. Across the lower part of the chamber is placed a hollow bridge, under which is a longitudinal slit communicating with a channel through which air is supplied by a steam jet. Cleaning doors are placed on each side of the bridge, so that a bar can be thrust right through the charge. A cleaning door is also provided at the end of the air channel. The fuel is fed through a bell and hopper, and gas is led away by a side opening. A blow-off valve is fitted in the gas main.

The gas is used for heating purposes in shipbuilding, boilermaking, &c. The furnace is on the regenerative system, and consists of a long narrow chamber widened at one end, and each end is provided with a door. There are openings in the sides and ends for the entrance and escape of the gases. Illustrations are given of the plant.*

* *Engineer*, vol. xvii. pp. 3, 18.

Recent Improvements in the Production of Water Gas.—In paper read by M. Quaglio* before the Berlin Society of Arts, the ıthor discussed the improvements made in the production of water ıs during the last ten years, and reference was more especially made ı the plant erected at Essen by Messrs. Schultz and Knaudt, and to ıe installation at Witkowitz.

The improvements in the construction of the appliances used in the ·oduction of water gas have mainly been in the direction of simplifi-ıtion. The author observes that for each cubic foot of water gas ·oduced four cubic feet of ordinary producer gas have also to be ade. In the Witkowitz plant a water-cooled ring is attached to the ·oducer, on which the slag or clinker collects, and from which it can be adily removed. The author gives details relating to the construction the Witkowitz plant, and states that the water gas and the producer s that are made have the following volumetric compositions :—

Description.	Producer Gas.	Water Gas.
	Per Cent.	Per Cent.
Carbonic anhydride . . .	1·7	1·0
Carbonic oxide	31·7	46·0
Hydrogen	2·8	48·0
Nitrogen	64·8	$N+CH_4$, 5·0
Total . . .	101·0	100.0

The relative cost of water gas as compared with that of producer gas comes less with the diminution in the quantity of producer gas cessarily made in the production of the water gas. At Witkowitz e cost of the cubic metre of water gas was at first 0·5 kreuzer (2·8d. r 1000 cubic feet), that of the cubic metre of producer gas being ly 0·17 kreuzer (1d. per 1000 feet), but for equal heat effect the lative cost is as 177 is to 172. In Germany the cost of the cubic ɜtre is estimated at from 1 to 4 pfennig (about 3½d. to 14d. per 1000 bic feet). Practice has shown, however, that for equal working ·ect in a water gas furnace only about 50 per cent. of the heat is quired that is necessary in a furnace working with ordinary producer s. In conclusion, the author states that the inclusive cost of the ıildings and plant required for the production of 100 cubic metres

* *Verhandlungen des Vereins zur Beförderung des Gewerbfleisses*, 1888, pp. 123-134.

(3531·7 cubic feet) of water gas per hour would be £1350, that of a 500 cubic metre plant £3000, and that of a 1000 cubic metre plant £3500. According to the nature of the fuel used, the amount of it which would be required for the production of the cubic yard of water gas would vary from 1·4 lb. to 2·6 lbs. The labour required for the smaller plant would be that of one man per shift, whilst for the larger plants two men per shift would be required. For the blast about one-fiftieth of a horse-power is required per cubic metre of gas per hour. To avoid the danger due to the want of smell of the water gas a small quantity of mercaptan or nitrobenzol may be added to it to render it odorous.

The Use of Water Gas.—F. W. Lürmann* observes that he employed steam in gas producers as far back as 1869, and discussed the subject in *Dingler's Journal* for 1870. The author draws attention to the suggestions he then made, and more especially to the possible use of cupola gas producers arranged so as to allow slag to flow away.

The Loomis Water Gas Plant.—The Loomis system of water gas manufacture differs from that in ordinary use, in that the generator is worked by a down draught during the period when the coal is being brought to incandescence, previous to the introduction of steam for the production of water gas.

A plant on this system has been erected at Tacony, Pennsylvania. It consists of four producers, each 9 feet in outside and 6 feet in inside diameter, and 14 feet high, with a fire-brick grate and an air-tight charging hopper. The results obtained are stated to show that from 40,000 to 50,000 cubic feet of water gas are produced for every 130,000 or 140,000 cubic feet of producer gas obtained in the heating-up stage. The producers are able to convert into gas eight tons of coal in the day of twenty-four hours.†

VIII.—*COAL MINING.*

Improvements in Mining Appliances.—Mr. Ralph Moore, Inspector of Mines for the Eastern District of Scotland, on his retirement from that post, which he has held for twenty-seven years, received

* *Stahl und Eisen*, vol. viii. pp. 831–833.
† *Iron Age*, vol. xlii. p. 458.

farewell present from a number of gentlemen connected with the Scottish coal and iron trades. In thanking the donors, Mr. Moore* gave some interesting details of the improvement in mining appliances since he first was a colliery manager, forty-eight years ago. At that date, he said, there were cages at two or three collieries in the county of Edinburgh, but there was none in Lanarkshire. The coals were all drawn in corbes. A few years after there was not a single colliery without them. Pug engines were first introduced about 1845. Ventilating furnaces were of the most primitive description. Fans were unknown. The first fan in Scotland was put up in 1868; now there were hundreds, and scarcely any one thought of doing without a fan. The amount of ventilation in a colliery was from 8000 to 10,000 down to as low as 1000 cubic feet per minute, and now there were some collieries in the district with 250,000 cubic feet per minute. Last year he made the calculation that eight tons of air were sent into the mines for every ton of coals extracted. Wire ropes were not in use at the time of which he spoke; now there was nothing else. Underground mechanical haulage was practically unknown; now it was universal. Many large collieries had only one shaft, now all had two. A coal-owner putting out 100,000 tons a year was a large coal-owner. There were coal-owners now putting out over 600,000 annually. As a consequence of all these improvements, the output of minerals in the district, which in 1856 was 4,500,000 tons, was now 17,000,000 tons, and the death-rate, which in 1853 was one for every 250 persons employed, is now about one in 800.

Application of Electricity to Mining.—In a paper recently read before the Ohio Institute of Mining Engineers, reference was made to the successful installation of electric power at the Drain Colliery, Osceola, Pennsylvania. In this colliery there is an electric motor for working a Lechner coal-cutter. The motor weighs less than 1000 lbs., and is of 10 horse-power. It is mounted on a truck that is placed on the mine tramway. The motor is connected with the cutter by a tarred hemp rope, the connection being of sufficient length to enable the cutter to be worked at a distance of thirty feet. The dynamo is 1600 feet away from the motor. Only two men are required for working the plant, and these two men excavate 100 tons in ten hours. Seventy per cent. of the primal energy is given off for work from the

* *Nature*, vol. xl. 61.

motor pulley to the cutter. The cost of the electrical plant, including generator, conductors, and motor, was £325.*

A New Coal-Boring Machine.—A new machine for this purpose, designed at the Western Machine Works, Ottumwa, Iowa, is illustrated in the *Iron Age*.† The machine is very light, and readily adjusted, and can be used for any desired thickness of coal.

Refilling Colleries.—At the Kohinoor Colliery, Shenandoah, United States, the following device has been adopted for refilling the parts of the colliery from which the coal has been removed:—

A coal-dirt conveyer, consisting of a series of semi-circular shoots, and an endless chain with scrapers attached, automatically conveys the fine refuse from the coal breakers to an elevation, whence it is discharged into a second shoot. As the coal-dirt falls on the second shoot, the water pumped from the colliery mixes with it, and carries the fine coal-dirt, in the form of a thick mud, back through a jig or puddling hole into those parts of the colliery from which the coal has been removed. The coal-dirt settles to the bottom of the breasts and packs closely. The cost of thus puddling the refuse matter back into the mines, about 1½d. to 2d. per cubic yard, is comparatively very small compared with the value of the pillars of marketable coal of which the mines may be safely "robbed," and the security obtained for dwellings and railroad property on the surface, above the mines. Already more than two acres beneath the city of Shenandoah, from which the coal had been mined, have been again solidly refilled with the coal dirt.‡

Goaf Stowing.—Mr. H. Fletcher§ describes the effect of goaf stowing as reducing the danger from sudden rushes of gas caused by large falls of the roof, and also obviating the presence of spaces where gas can accumulate. The author also describes the working of the Ladyshore Collieries, Bolton.

Winding from Shafts.—At a meeting of the Engineers' Club of Philadelphia, Mr. A. H. Storrs described Poore's system of winding

* *The Electrician*, vol. xxii. p. 390.
† Vol. xlii. p. 579.
‡ *Iron Age*, vol. xlii. p. 583.
§ *Transactions of the Manchester Geological Society*, vol. xx. pp. 173-193.

with an endless rope. This system of winding is said to be particularly applicable to shafts of great depth. The advantages claimed are that it enables smaller engines to do the work, and effects a saving, as against the ordinary engines with drums, of about 50 per cent. in the first cost of the plant, and greatly decreases the running expenses, owing to the much smaller steam consumption; the ropes, working altogether in straight lines, should be longer lived, and worn-out hoisting ropes can be used for tail ropes; the cages run with less oscillation, the length of the rope is easily adjusted, and there is decreased danger of overwinding. The plant, as put in at the Neilson Colliery, consists of a pair of 28 by 60 inch horizontal engines, with a pair of wood-faced rope sheaves and brake wheel, all 14 feet in diameter, placed on the crank shaft. In addition to the regular brake for controlling the engines, an extra brake is provided with which the engineer can clamp the winding rope into the grooves of the engine sheaves in case of an emergency, such as the breaking of a rope. The tower-head sheaves are 12 feet in diameter. The winding rope is made of special steel, $1\frac{1}{2}$ inch in diameter, with a hemp centre, and runs from one cage over the head sheave to one of the engine sheaves, thence to and around a transfer sheave to the other engine sheave, and over the other head sheave to the other cage. The cages are also connected by a $1\frac{1}{2}$-inch iron wire tail rope, running from the bottom of one cage around a small sump sheave at the bottom of the shaft, and to the bottom of the other cage. This sump sheave hangs in the bight of the tail rope, and is free to move on vertical guides. The transfer sheave before mentioned is a wrought spoke wheel about 16 feet in diameter, so set that it can be moved towards, or away from, the engine sheaves, thus adjusting the length of the rope, and its position is always such that the lines of pull of the ropes are tangents both to itself and to the engine sheaves, thus avoiding any side wear on the grooves or rope. The total hoist is about 1330 feet. The cages weigh 3 tons each, and an empty truck about $1\frac{1}{2}$ ton. The trucks carry from $2\frac{1}{2}$ to 3 tons of coal or stone. The cages, trucks, and ropes, being perfectly balanced, the load in the truck and the friction of the machinery is all that the engines have to overcome, and, as this load is constant, a steadier engine speed is obtained than with drums.*

Remarkable Mine Output.—In the month of January 1889 the

* This system of winding appears to be nothing more than a modification of the well-known Koepe system.

colliery of the Lehigh and Wilkesbarre Coal Company, Pennsylvania, worked 18 days and 8 hours, and raised from one shaft, as the average per day of 10 hours, 1181 trucks, or 2360 tons of coal and waste. This is equal to 118 trucks, or 236 tons an hour, or nearly two trucks raised each minute, as the average working rate through the month. The shaft has a double hoistway, and is 300 feet in depth. The trucks used are, in inside clear dimensions, 7 feet 5 inches long, 3 feet 7½ inches wide, and 2 feet 10 inches high, and have a capacity of about 70 cubic feet.*

Signalling from Mining Cages.—For this purpose Mr. W. Armstrong† inserts an insulated wire into a strand of the winding rope. At the drum end connection is made through the drum with a battery and bell. A push in the cage enables the circuit to be completed, and signals given when the cage is at any point in the shaft.

Electric Haulage.—Mr. G. B. Walker‡ considers the only form in which electricity can be applied to haulage in mines is by the use of a locomotive carrying accumulators; any other system being impracticable on account of the difficulties connected with the conductors. If the roads are suitable, the locomotive can serve any part of the mine indifferently, unlike any system of rope-haulage, and besides is more economical, as so much power is not wasted. The various obstacles to the use of locomotives are the grades of the roads, the necessity for recharging, and the generation of sparks, especially in fiery or dusty mines. The Lidgett Colliery is peculiarly adapted for the use of locomotives, as the strata are exceptionally flat. The engine runs on a track 1 feet 9 inches gauge in a drift 4 feet high by 4 feet 6 inches wide, and its total weight does not exceed 2½ tons. On an incline of 1 in 70 the engine just moves a train of twenty loaded corves weighing 11 tons, and with a load of 8½ tons a speed of three miles an hour was obtained. On a level the load was thirty corves.

The battery consists of forty-four modified Tatham cells, each weighing 53 lbs. and having a capacity of 150 ampère-hours. Taking 40 ampères as the average discharge, the weight of these cells per horse-power is nearly 500 lbs. The motor is of the ordinary Immisch type, and weighs 4½ cwt., and gives four horse-power at 800 revolutions per minute.

* *Engineering and Mining Journal*, vol. xlvii. p. 203.

† *Engineering*, vol. xlvii. p. 143.

‡ *Transactions of the Midland Institute of Mining Engineers*, vol. xi. pp. 317-332.

Movable Platform for Inclined Planes in Mines.—C. Ruidant * describes, with the aid of detailed drawings, an apparatus designed to effect an easy junction between steeply-inclined planes and the branch roads driven on the level right or left, where the use of an ordinary turnplate would be inconvenient.

Timbering in Mines.—Mr. R. S. Broome † calls attention to the large death-rates from falls from the roof and sides, these amounting to 45·37 and 62·16 per cent. in anthracite and in bituminous regions respectively. This state of affairs evidently demands that the timbering and packing of mines shall be well carried out. Great stress is laid on the necessity for using the long-wall system and of timbering before any pressure begins to show. Various methods of placing the timbers are described. The author is of opinion that it is best to place the thick end of a prop at the top, partly because it is then easiest to draw. The bar and chain should always be used for withdrawing the timbers. Sprags should be liberally made use of. The author also refers to the packing, which must be consistently carried out.

A series of articles is also given in the *Colliery Guardian* ‡ on methods of opening, working, and ventilating mines. Another series by Mr. J. Hayes is given in the *Colliery Manager* § on "Notes on the Opening and Development of a New Colliery."

Rapid Driving of a Cross-Cut.—A. Tschebull, ‖ in a paper read before the Austrian Society of Engineers and Architects, describes the method which was employed in lignite mining near Gran, in Hungary, in a case in which it was necessary to open up some lignite beds as rapidly as possible. Hand-boring was alone possible, and the question was how to proceed with the greatest rapidity in the driving, the formation being Eocene slaty sandstones and shale, and Triassic limestone. A shaft had been sunk to a depth of about 330 feet, and this had afterwards filled with water for about half its depth. A cross-cut was then made, which commenced just above the water-level, the progress made in Eocene rocks during the first month having been 159 feet. The author describes the arrangements made with a view to expedite the cross-cutting, the division of labour, and the

* *Revue Universelle des Mines*, vol. ii. p. 79.
† *Colliery Guardian*, vol. lvi. pp. 888-924, and lvii. p. 27.
‡ Vols. lvi. and lvii.
§ Vol. v.
‖ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxvii. pp. 91-93.

method of payment for work done. To enable the material brought down by the shots to be cleared away with greater rapidity, one or two flat pieces of stout sheet-iron, about 6½ feet by 3¼ feet, were placed before the bore-holes previous to firing. Most of the rock brought down by the shots remained on these sheets, and was much more readily removed from them than would have been possible if the bed had consisted of the rough floor of the level. In the eight hours' shift the division of time was as follows:—

	Hours.
Putting in the bore-holes	5–5½
Charging and firing	1
Allowing smoke to clear away	½–¾
Clearing the level, &c., ...	¾–1½

Pumping Engine at the Bernissart Colliery.—A. Ledent* describes, with the aid of detailed drawings, the underground pumping engine erected in 1886 at the Bernissart Colliery. It is fixed at a depth of 131 fathoms. The two horizontal cylinders, coupled at right angles, are 17¾ inches in diameter by 35½ inches stroke, and the four single-acting plungers, with the same stroke, are each 4½ inches in diameter. The fly-wheel is 11½ feet in diameter and weighs 4 tons. The ordinary speed is 43 revolutions per minute. The total cost of the engine when fixed was £1670. The useful effect of the pumps is claimed to be 80 per cent. of the theoretical value.

This type of engine, forcing at a single lift, is recommended for depths not exceeding 250 fathoms. For greater depths, it is preferred to fix a second engine at half the depth, and to pump at two stages.

Electric Lighting at the Ynishir Colliery.—P. F. Chalon† describes the different methods of lighting in use at the Ynishir Colliery, Wales. At this colliery the surface lighting is effected by the aid of incandescent lamps of the Swan-Edison type, each of 16-candle power, and one arc lamp placed on a support at a height of 26 feet above the ground. In the deep workings, twenty-five 16-candle power incandescent lamps are in use. The author describes the mode of arrangement of the electrical plant employed, as well as the signals in use. Altogether 2000 yards of electric conductors have been laid down.

Tonite is the explosive used in blasting, the bore-hole being filled

* *Revue Universelle des Mines*, vol. ii. p. 1; *Minutes of Proceedings of the Institution of Civil Engineers*, vol. xciv. p. 374.

† *Génie Civil*, vol. xiv. pp. 72-74.

with water. The electrical discharge employed is illustrated by the aid of a sketch.

Rules relating to the general arrangement of electrical plant for colliery purposes are appended by the author.

Electric Lighting in Mines.—Mr. Wallis * considers the method of lighting collieries by the electric light. The dynamos could be driven from the fan engine, and the current led into the pit by main leads with branch circuits, so as to supply either arc or incandescent lamps or both on the same circuit. The incandescent system is in general the most suitable; accumulators, however, could be used. Taking a colliery turning out 1000 tons daily, the cost for electric light, gas, and paraffin would be 0·05, 0·13, and 0·116 penny per ton respectively. Amongst other conveniences, the light can be turned off and on at any time. The current can be used for shot firing, for signalling, and for giving power.

Safety Lamps.—Mr. O. R. Swete, on behalf of Mr. J. Higson,† describes an electric lamp made by the Mining and General Electric Lamp Company. The battery consists of two cells, giving four volts current and one candle-power for twelve hours. The whole apparatus weighs five pounds. The charging takes five hours from a dynamo. A covering of toughened glass is placed outside the lamp, and if this is broken the circuit is cut. For 1000 lamps the total cost of lamps, plant, &c., would be £1090, and the maintenance 2½d. per week per lamp.

Mr. J. S. Burrows ‡ gave results of trials with the Edison and Swan lamp, and mentioned the superiority of light-penetration over the Marsaut lamp.

The latest form of the Schanschieff lamp is reduced in price to £1, and the maintenance to 3d. per week. §|

Ventilation of Mines.—The Report of the Ventilation of Mines Board, Victoria, on the mines at Sandhurst has been presented. For natural ventilation it is recommended that winzes should be carried down simultaneously with the shafts, and that natural ventilation in long cross-cuts should be assisted by mechanical means. Under favour-

* *North Staffordshire Institute of Mining and Mechanical Engineers.*

† *Transactions of the Manchester Geological Society*, vol. xx. pp. 60–71.

‡ *Ibid.*, vol. xx. pp. 71–76.

§ *North of England Institute. Chesterfield and Midland Counties Institute of Engineers.*

able circumstances, holing through from one mine to another secures good ventilation to the depth at which the holing is made. All shafts in future should be close timbered, and should be large enough to carry ventilating pipes. The bark should be taken off all timber before it is sent down. Proper sanitary regulations should be enforced and disinfectants supplied. Water spray should be used for laying dust, and thermometers should be fixed in the principal workings.

Mr. R. P. W. Oswald * describes the various causes of explosions in mines, and gives details of several. The various means by which they can be prevented are mentioned.

Theory of Centrifugal Ventilators.—Mr. J. Henrotte † sets forth a theory and gives formulæ whereby the effects, &c., can be calculated. He deduces from the application of the theory to certain experiments that the useful effects and percentage of indicated horse-power utilised by centrifugal fans are larger as the mines are more difficult to ventilate. A large fan moving slowly has a greater useful effect than a smaller fan moving quickly, but the small fan absorbs less work. An excessively large fan will show upon all mines a constant useful effect, and so will give useful effects on a mine easily ventilated equal to that given by a small fan on a mine difficult to ventilate. Diffusers have theoretically no influence on the increase of the useful effect. In small fans running rapidly the blades should be turned backwards.

Mr. H. Bocket ‡ gives very full details of experimental determinations of the results and working of a Capell fan and the consequences deduced from these results. His papers are designed to elucidate the apparent paradox that more work is done by the fan than is accounted for by the work put into it, and he shows that a great deal depends on the manner in which the pressure of the air is measured and on the temperature and pressure. He finally states that the Capell fan is far superior to others.

Dr. Oliver Lodge § has also written on the same subject, and gives formulæ for determining the pressure, velocity, temperature, and density in every part of the delivery trunk; also the amount of air transmitted per second, the total power of the blast, and the effective power of the fan.

* *Whitehaven (Cumberland) Scientific Association. The Colliery Manager*, vol. v. pp. 41-43.

† *Colliery Guardian*, vol. lvi. pp. 455, 529, 733.

‡ *The Engineer*, vol. lxvi.

§ *Ibid.*, vol. lxvii. pp. 1, 46.

The Air of Coal Mines.—Dr. T. J. Nasmyth * has exhaustively investigated the physical, chemical, and biological conditions of the air in coal mines. Readings of wet and dry bulb thermometers for three months showed that the temperature and moisture were fairly constant, though considerable variations occurred above ground. The air was generally saturated with aqueous vapour, while the temperature varied from 55° F. to 53° F. At all times there was sufficient ventilation, as shown by an anemometer. Carbonic anhydride was estimated by Pettenkofer's method, and was found to increase with the depth of the mine. In mines under 100 fathoms deep the percentage was 0·181, whilst it rose to 0·219 over that depth. Carnelly's method for estimating the organic matters present showed that a large quantity of oxygen was required to oxidise these substances. Franke's method showed that the oxygen diminished when the ventilation was bad, but the author does not place much value on this method of determining the condition of the air. In the biological investigations, Hesse's method of collecting and estimating the bacteria present was used, and the author describes at length the variety and frequency of the organisms which occur. Reference is also made to the health of miners, and the same subject is discussed by Dr. J. T. Arlidge † in four lectures on occupations and trades in relation to public health, with special reference to the effect of dust on miners, and also on those engaged in grinding needles, &c.

The Prevention of Colliery Fires.—A. Honl ‡ observes that the most certain method for preventing such fires must of necessity consist in shutting out the air. The geological conditions under which the coal is found are of great importance. Thus in the Rossitz-Oslavan coalfield the "pyritic" coal is considered liable to fire, as also is the case in the Ostrau district, but the danger is less where pure sandstone forms the hanging wall than it is where the coal is covered by bituminous slate. Similarly in the Kladno and Leoben districts the bituminous slate on the hanging wall is liable to give rise to fires. The signs of the existence of a fire are many and generally known.

In planning a new colliery, care should be taken to drive as few levels as possible—only two as a rule—to limit the surface of the coal exposed to oxidation, and care must also be taken to shut off any fires

* *Transactions of the Mining Institute of Scotland*, vol. x. pp. 161–189.

† *British Medical Journal*, Nos. 1472–1475, pp. 580, 642, 702, 766.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxvi. pp. 639, 646.

which may exist in old workings. In every case the temperature of the workings should be kept low by good ventilation, except in those places where the temperature has already risen too high to render this method of prevention possible. In such cases the only thing to do is to use as little fresh air as possible, and to increase the rapidity of working, and mine that portion of the coal as quickly as the working conditions will permit. The author describes the methods employed in 1869 in opening up certain collieries in the Innerberg district.

Fire-Damp Meter.—At the annual conversazione held by the Royal Society on May 8, Pitkin and Niblett's fire-damp meter was exhibited. By means of this instrument it is possible to detect and estimate the percentage of oxygen or hydrogen in mixtures of these gases. In its simplest form it consists of two ordinary cylindrical bulbed mercurial thermometers. These are mounted on a suitable base, and are then graduated off in the ordinary way to Fahrenheit or Centigrade scale. One tube registers the temperature of the mixed gases. The other, which is the gas indicator, has its bulb coated with one of those metals which, when in a very finely divided state, have the peculiar property of occluding and facilitating the chemical combination of certain gases. When placed in a gaseous mixture, and during the combination of the gases due to the above property of the metal, a considerable amount of heat is developed. The heat generated thus produces a corresponding rise in the mercurial column. To read the instrument, the difference between the two scale readings is taken, and then, by comparison with a table supplied with each instrument, the percentage of gas may be read off. In the case of fire-damp and air or coal-gas and air, the amount of heat developed appears to correspond approximately to the explosive activity of the mixed gases. A sliding scale may be fixed on the instrument, which can be graduated in terms of percentage of any particular gas.*

Employment of Explosives in Fiery Mines.—In 1887 a French Government Commission was instituted to study the question of the employment of explosives in fiery mines. The experiments were carried out at the Sevran-Livry powder-mill. The conclusions deduced from the experiments were that if the majority of explosives actually employed in mining operations ignite mixtures of air and fire-damp, they should be mixed with substances that remove this property from them, such

* *Nature*, vol. xl. p. 66.

as sodium carbonate, sodium sulphate, &c. There are also certain explosives, such as bellite, Favier powder, &c., that realise more or less completely the conditions demanded. In a supplementary report the conclusions of the first report are confirmed by further experiments. The employment of ammonium nitrate is advocated as the most suitable means of lowering the temperature of combustion.*

The Report, which has been drawn up by M. Haton de la Goupillière,† states that black powder is very dangerous even when used with the best forms of water-cartridge. It is not, however, merely the ordinary black powder which is dangerous, but the danger exists in the case of every nitrated powder which is not, strictly speaking, "detonating." The different varieties of dynamite belong to this dangerous class of explosives, but they are much less dangerous than ordinary black powder. The different varieties of dynamite again vary greatly in the risk attached to their use. Thus gelatine dynamite (dynamite-gomme) is much more dangerous than is ordinary siliceous dynamite. The views expressed by Mallard and Le Châtelier have led to the determination of the composition which should be theoretically given to safe forms of explosives, and practice has proved the accuracy of these theoretical statements. The safest explosives, then, are those consisting of varying quantities of ammonium nitrate, either mixed with other explosives, such as dynamite, detonating at a high temperature but yielding non-combustible products, or mixed with some substance combustible in itself, or yielding on detonating combustible products, such as ammonium cupro-nitrate, naphthaline, mononitro-naphthaline, or binitro-benzene.

The mixtures of the first category differ essentially from the ammonium nitrate dynamites now sold, as in those the addition of the ammonium nitrate is intended to increase the force of the explosive, whilst in the new explosives it is used for the purpose of diminishing the explosive force. The experiments made further appear to show that the danger of the explosion increases with the size of the charge. The safety fuse, too, has dangers inherent to its use. It should only be employed with the greatest possible care, and ought really to be abandoned altogether. The Report does not suggest the use of any drastic measures of reform, but merely proposes that the Ministry should issue a circular drawing attention to the results of the experiments, and this has since been done.

* *Annales des Mines*, vol. xiv. pp. 197-376.
† *Génie Civil*, vol. xiv. pp. 89-93.

Trials of Explosives.—A further* series of trials of various explosives has been made in the experimental level at the König Colliery near Neunkirchen, in the Saarbrücken district. H. Lohmann† observes that the admixture of dynamite with hydrated crystallised salts is a great improvement over the old forms of explosives intended for use in fiery mines. Dynamite mixed with 40 per cent. of such hydrated salts (soda) gives a comparatively high degree of safety both as regards fire-damp and coal-dust, and gives a large percentage of lump coal. *Carbonite.*—The samples of carbonite tried in this series of experiments showed a much higher degree of safety both for fire-damp and coal-dust. *Water cartridges*, in which the explosive is surrounded on all sides by water, are very safe. *Ammonia dynamite.*—The sample tested consisted of 40 per cent. of ammonium carbonate, 10 per cent. of potassium nitrate, and 50 per cent. of nitro-glycerine and kieselguhr, this latter being added in a quantity sufficient to produce a plastic but not an oily cartridge. Other ammonium salts, such as the oxalate, may be used instead of the carbonate, provided a sufficient quantity of an oxidising substance is added to convert the whole of the carbonic oxide produced into carbonic anhydride. Ammonium carbonate proves to be less suitable than the oxalate in preventing explosions. A useful mixture consists of 45 per cent. of ammonium oxalate, 15 per cent. of sodium nitrate, and 40 per cent. of nitroglycerine and kieselguhr. The results of further experiments made with explosives consisting of ordinary black powder, to which ammonium carbonate was added, led to the belief that by changing the ordinary composition of the powder it will become possible to use it in the presence of fire-damp or coal-dust. It appears probable that a fine-grained powder of the composition of sporting-powder, in which ammonium oxalate is substituted for a portion of the carbon, might prove a suitable explosive, and the author is experimenting in this direction. *Securite.*—Whilst further experiments with this explosive in its old form gave bad results, a greatly improved and satisfactory variety was also tried. *Roburite* gave perfectly satisfactory results when employed in the absence of fire-damp. It is generally thought that this explosive consists of chlorinated and nitrated hydrocarbons, but the analysis of a sample showed not even a trace of chlorine to be present. The *Wolf benzene lamp* was experimented with, in order to ascertain whether the explosion of the lighting capsule inside the lamp would lead to an

* *Journal of the Iron and Steel Institute*, 1885, pp. 278, 625.

† *Zeitschrift für das Berg- Hütten- und Salinenwesen*, vol. xxxvii. p. 83.

ignition of gas outside the lamp. This only occurred on the 240th explosion, after the lamp had become very hot.

In a further series of explosions a steel mortar was used, and the explosive charge did not exceed 250 grammes. *Ammonia dynamite* proved itself to be a very safe explosive. *Kieselguhr dynamite* and *gelatine dynamite* are about equally dangerous. *Roburite* is safer than *gelatine dynamite*, but worse than *ammonia dynamite;* but it is believed that an improved form of roburite has recently been manufactured. *Carbonite*, the new form of *securite*, and dynamite mixed with 40 per cent. of soda (*Wetterdynamit*), are very safe explosives. *Blasting gelatine* is extremely dangerous. *Carbo-dynamite* gave negative results. *Favierite.*—This explosive is usually compressed into small wooden cylinders, and is thus protected from damp. As, however, the compressed explosive is difficult to ignite, a hollow is left in the centre of the cartridge, which is then filled with the loose explosive, the ignition of which explodes the compressed portion. As with *roburite* and *securite*, the transport of *favierite* is very free from danger, and it can be immediately destroyed by water. To prove its safety when used in the presence of fire-damp or coal-dust, experiments were made with five different sorts, one of which—No. IV.—proved to be a very safe explosive. It consists of dinitro-benzene and mononitro-naphthaline, together with ammonium and sodium nitrates.

Mr. R. W. Clarke * gives some notes on experiments with carbonite and other explosives at the Nunnery Collieries. The carbonite was very successful in bringing down the coal after holing, though a heavy charge did not produce much effect when the coal was not holed. Roburite was rather more successful. No flame was observed in either case, and the carbonite left no appreciable fumes.

Bellite.—Experiments on bellite were conducted by Mr. Lamm † and Mr. C. N. Hake at Messrs. Bell Brothers' Ironworks, Middlesbrough. This explosive consists of five parts of ammonium nitrate with one part of di- or tri-nitrobenzene, and is manufactured in the form of a loose yellowish powder or as cartridges. It can only be exploded by a detonator, and it gives off no fumes. It presents no danger in manufacture and requires no thawing. Amongst other experiments, half a ton was dropped from a height of twenty feet on some naked cartridges laid on an iron plate without exploding them.

* *Journal of the British Society of Mining Students*, vol. xi. pp. 84–86.
‡ *Iron*, vol. xxxii. p. 409.

A cartridge exploded by detonation on the wooden lid of a box containing bellite cartridges did not explode them when the lid was three-quarters of an inch thick, though it did when the lid was only three-eighths thick. The material scarcely ignites when thrown into a fire, but simply melts away. Comparative experiments on rails made between bellite and No. 1 dynamite, showed a slight advantage in favour of the former. As a rule, the local destruction with dynamite was more severe, whilst the bellite produced a more extended effect. In other experiments three lbs. of bellite was buried four feet deep in earth and exploded. A circular cavity 11 feet in diameter was made, and the earth was shot to a height of 150 feet, as compared with only 25 feet for gunpowder.

A second series of experiments was carried out in the ironstone mines at North Skelton. After several failures, which were ascribed to faulty fuses, &c., it was found that good results were obtained, whilst the bellite used was only half the weight of the powder which would have been required. No flame could be seen with the bellite in open daylight, and no fumes were detected in the underground workings after an explosion.

A series of experiments * with this explosive was made at Chadwell Heath. Half a cartridge when thrown on a fire burnt slowly with a reddish flame. The other half when tamped with clay bulged a wrought iron plate three-eighths of an inch thick to a depth of two inches. Experiments with falling weights failed to explode the material. It was not exploded when covered with a charge of powder. Comparative experiments with dynamite were made, showing that the action of dynamite is more local. Its adaptability for military purposes was also shown.

Dahmen Safety Dynamite.—Mr. P. F. Nursey † has carried out experiments with this explosive, which consists of dynamite with some substance added to prevent its freezing. Comparative experiments showed that it was rather stronger than No. 1 dynamite, whilst it remained plastic and exploded readily at low temperatures, thus obviating the necessity of thawing the material. Mr. C. Napier Hake ‡ also states that it is slightly less sensitive than No. 1 dynamite, and that the manufacture is somewhat less dangerous.

* *Engineering*, vol. xlvii. p. 128.
† *Iron*, vol. xxxiii. p. 89.
‡ *Ibid.*, vol. xxxiii. p. 89.

Emmensite.—This explosive * is prepared by dissolving an excess of picric acid in nitric acid having a specific gravity of from 50° to 60° Baumé at a low temperature. The liquid is evaporated. Bright yellow crystals, and then others of a lighter colour, are precipitated, and after that a light grey powder. Five parts of these crystals are melted with five parts of ammonium nitrate over a paraffin bath; when fused, six parts of picric acid are added, and the mixture poured into moulds. The emmensite is bright yellow, amorphous solid, completely odourless, and having a bitter taste. It has a spongy texture and a specific gravity of 1·7. Several qualities are made, some resembling dynamite, whilst others can be used for fire-arms. It is but slightly sensitive to shock.

Dynamite and Safety Cartridges.—J. Mayer,† gives a historical sketch of the rise and progress of water-cartridges, and then proceeds to describe the so-called "fire-damp dynamite," the results of a large number of experiments with this explosive being given. The variety of this explosive first produced was gelatine dynamite mixed with crystallised soda; but it proved to be difficult to explode, and its use was finally abandoned. The gelatine dynamite was then replaced by kieselguhr dynamite; and a suitable mixture, which was at length found, had the following composition: nitro-glycerine, 52 per cent.; kieselguhr, 14; and crystallised soda, 34 per cent. The next important improvement consisted in using ammonium chloride in the place of the soda, the use of ammonium carbonate for this purpose having been proved to be unsatisfactory, as the material readily decomposed; the quantity of ammonium chloride added being in the ratio of from 40 per cent. of ammonium chloride to 60 per cent. of nitro-glycerine. In another explosive of this type these quantities are reversed. The ammonium chloride fumes following the explosion are, however, very unpleasant. The next attempts were in the direction of finding some more stable salt to use in the place of the hydrated soda. In this way the magnesium sulphate dynamites came into existence. They proved, however, to be both less safe and less stable than the soda explosives. The author appends the results of a large number of comparative trials of various kinds of fire-damp dynamite and of ordinary dynamite, which were made in an experimental level at a colliery in Polish Ostrau.

* *Engineering*, vol. xlvii. p. 66.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxvii. pp. 111-113, 137-139, 152-156, 161-163.

These experiments showed that the soda fire-damp dynamite was far better than all the other varieties that were tried, even the most dangerous varieties of coal-dust not having been exploded by it. The ammonia compound, although it gave less favourable results than did that containing soda, proved to be much safer than ordinary dynamite to which no addition had been made. Even gas mixtures containing 9 per cent. of fire-damp were not exploded by the free-lying soda dynamite used, provided the weight of the charge did not exceed 150 grammes. Blown-out shots with charges twice the above weight failed to explode the gas mixture.

Hengst Powder.—This powder, which has recently been tested, is prepared from straw, pulverised, chemically treated, and finished in a granular form for use. It is smokeless and flameless, and weight for weight is 150 per cent. stronger than gunpowder. It is not exploded by concussion. When compressed it will probably be applicable for blasting.*

Roburite.—Mr. J. Hilton,† after describing the characteristics of roburite, gave the following rules for its use, drawn from experience gained in firing over 3500 charges.

1. Roburite can only be exploded effectively by a very strong detonator containing one gramme of fulminate of mercury.

2. The drill-hole should only be a trifle larger than the diameter of the cartridge, and is more suitable when machine-drilled.

3. Open one end of the cartridge, bore a hole down its centre with a wooden peg, then insert the detonator well into the middle of the cartridge, and next tie the covering firmly to the fuse.

4. In tamping, use dry material, and ram the hole lightly for the first 3 or 4 inches. Afterwards tamp firmly for not less than a foot with clay or damped borings. This rule is most important, as the safety of the explosive depends on the tamping.

5. Fire the detonators with an electric fuse where fire-damp is given off or coal-dust is present.

6. Store the roburite in a dry place, and fire quickly if the hole is wet.

7. If the charge misses fire, disconnect the cable and wait ten minutes.

* *Iron*, vol. xxxiii. p. 202.

† *Transactions of the Manchester Geological Society*, vol. xx. pp. 92–106.

The author had not observed a flash more than once in each hundred shots, and then only to a slight degree. In the discussion it was stated by Mr. Cockson that roburite had $2\frac{1}{4}$ to $2\frac{3}{4}$ times the strength of compressed powder.

Mr. W. Watts * endorses the opinion of Mr. H. Bramall † that the fumes of roburite affect the health of the men using it. The fumes are very similar to those of tonite, but are heavier, and so linger longer in the workings.

Securite.—Experiments recently made at the Himmelfürst mine, near Freiberg, in Saxony, with reference to the relative amounts of gelatine dynamite and securite required for an equal amount of work done, showed that 550 parts of securite were equal in effect to 507 parts of the dynamite. The dynamite cartridge was unaffected by water, but the securite cartridges could not be exploded after having lain in water for several days. The use of blasting gelatine (Sprenggelatin) was found in similar experiments to be less advantageous than that of gelatine dynamite. ‡

Blasting.—Mr. H. Johnson § considers the question of underground blasting under four heads, namely, making and cleaning the hole, tamping and ramming it. He describes a drill with guide-discs attached to the stem, and also describes a cleaner, clay cartridges for tamping, and a tamping bar with a passage for the fuse. Tamping wedges with fuse-hole to prevent blown-out shots were also mentioned.

Various Methods of Firing Shots.—J. Mayer || observes that the explosions produced in collieries by the blasting are due to one or other of two causes: (1) the fuse used, and (2) the explosive. The first is probably the most frequent cause, as well as the most dangerous. The use of the Bickford fuse, the author states, is undoubtedly accompanied by danger. This, in fact, has long been recognised, and attempts have been made to use electric firing in its stead. This,

* *Transactions of the Manchester Geological Society*, vol. xx. pp. 211–214.

† *Ibid.*, vol. xx. pp. 158–162.

‡ *Sächisches Jahrbuch*, 1888, pt. ii. p. 106.

§ *The Colliery Guardian*, vol. lvi. p. 876; *North Staffordshire Institute of Mining and Mechanical Engineers.*

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxvii. pp. 47–50, 61–64, 84–87.

however, may, under certain circumstances, also prove an extremely dangerous method in view of the liability of sparks passing from one of the conducting wires to the other. Apart from the use of electricity the methods of firing that have been proposed, with a view to avoid the danger accompanying the use of the ordinary fuse, may be divided into two main classes: (1) those in which the fuse is retained, preventive arrangements being adopted, and (2) those in which a fuse proper is not employed. The author treats of various methods belonging to the first of these two classes, but he adds that he considers the whole class to be unsatisfactory in its very nature. The second class, on the other hand, appears correct as to its principle, and includes all methods which strive to cause the ignition to take place in the centre of the charge in the bore-hole, such methods including those involving friction, percussion, or other mechanical or chemical agency. The various methods are described by the author by the aid of numerous sketches, and in his general conclusions he remarks that the use of the majority of the various methods appears to entail a considerable degree of danger, in view especially of the fact that those who will have to employ them are usually unskilled, and to a certain extent careless. The necessary manipulation must not therefore be involved. In conclusion, the author describes the difficulties experienced in the collieries in Polish Ostrau, where the Lauer friction method was originally used, together with the improvements that have since been adopted, and he adds that the improved form now in use appears to fulfil every requirement.

Premature Explosions of Gunpowder.—Mr. J. Grundy* suggests that the hardening of copper and brass stemmers by constant use may cause them to be more likely to give sparks when struck against anything hard.

A second cause of premature explosions might be due to the compression of air in the bore-hole if the wadding were air-tight. A case was mentioned in which the collier wadded the hole with "a big handful of paper," and in pushing this down the powder exploded. The old experiment of igniting touch-paper in an air-tight cylinder, when a piston is forcibly pushed down therein, was performed to prove the case. When powder was used instead of touch-paper in this experiment, an explosion occurred.

* *Transactions of the Manchester Geological Society*, vol. xx. pp. 84-91.

Air-Compressing Machinery at Collieries.—Mr. J. Morison* points out the danger attending the use of light mineral oils for lubricating air-compressing machinery. On February 13, 1888, he examined at Newbattle Colliery, Dalkeith, the discharge pipes leading from an air-compressor to a receiver 50 feet away. The pipes were of cast iron, 6 inches inside diameter, and had flanged joints, the joints being made with india-rubber insertion screwed up between the flanges. The compressing cylinder was 24 inches in diameter by 4 feet stroke, and air was compressed up to 50 lbs. per square inch. The cylinder was fixed in a tank containing water, but no other method was used for cooling the air during compression. The temperature of the air leaving the compressor was found to vary between 320° and 370° F. when compressed up to 50 lbs. per square inch. The receiver was blown off daily. Some little time previously the pipes leading to the receiver appeared to be unusually hot, and soon two of the pipe joints between the cylinder and the receiver began to blow, while sparks were blowing with the air out of the joint, and the pipe was nearly red hot. On taking out the joints, they were found to be charred and burnt through, and the interior of the pipes was coated with a charred deposit, doubtless the residue of the combustion of lubricating oil which had been used in the cylinder. The oil ordinarily used was lard oil, but owing to a temporary want of this latter, for a short time previously use had been made of a mixture of a heavy mineral oil (high flash-point) with an oil bought as colza. The supposed colza oil was chiefly made up of thickened cotton-seed oil and intermediate mineral; its specific gravity was 0·91, and it had a strong mineral bloom, and flashed at 295° F. The author compared the circumstances of the two cases, and concluded that the flash-point of all oil used in air-compressing machines should be tested, or a guarantee should be obtained from the maker.

Measurement of Earth-Pressure in Mines.—In the mine at Stassfurt, belonging to the Prussian Government, the following contrivance has been adopted to measure the vertical change caused by the thrust of the strata. Wooden plugs, each a yard in length, are driven into the floor and roof. On to these plugs two iron tubes are screwed. The tubes do not meet, but a guide-pin attached to the lower one slides up and down within the upper one. At the side of the tubes a vertical board is fixed in such a way as not to touch the roof or floor.

* *Transactions of the North of England Institute of Mining and Mechanical Engineers*, vol. xxxviii. pp. 3–12.

Two metal frames are fixed to the board, so that their ends are in close proximity to the tubes. At the back of these frames is the centre of a lever, the shorter arm of which is connected with one of the tubes, whilst the longer arm serves as pointer that is free to move over a scale divided into centimetres on the board. The pointer is adjusted to zero, and the depression of the roof and the rise in the floor are indicated by the movements of the pointer.*

Plotting Colliery Surveys.—For plotting colliery surveys three methods are employed: (1) with a protractor, (2) by means of chords, and (3) by rectangular co-ordinates. In the first two methods there is the disadvantage that if any error is made in the plotting, it is carried throughout the whole of the survey. In the third method this is not the case, and any survey may be plotted with ease and rapidity, and with greater accuracy than is possible by any other method. But the preliminary calculations, whether made with natural sines and cosines, with logarithmic sines and cosines, or with traverse tables, occupy considerable time, and induce mine-surveyors, in cases where extreme accuracy is unnecessary, to prefer to plot their surveys with the protractor. In such cases, however, it is possible to employ the more accurate co-ordinate method, and at the same time to avoid the tedious preliminary calculations. This may be done by having recourse to the slide-rule, on which the logarithms of numbers, sines, and cosines are represented graphically in the form of scales. The bearing and length of a given line in the survey being known, its departure (easting or westing) may be found by placing the given angle as shown on the line of sines against the index at the back of the rule, and by reading off the number on the scale on the face of the slide corresponding with the given distance as shown on the upper scale. The latitude (northing or southing) is found in a similar way, the cosines being read off by reading the sines backwards. In order to avoid any confusion, complementary figures may be pencilled along the line of sines. In this way results may easily be obtained without calculation accurately to the first place of decimals.

In order to determine the degree of accuracy obtainable, Mr. R. H. Brough † has made a series of tests of a new form of slide-rule, 10 inches long, on which the graduations are not on wood, but on a white

* *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xxxvi. p. 244.

† *Colliery Guardian*, vol. lvii. p. 587.

substance resembling ivory (celluloid). They are in black lines, and very agreeable to read. The tests, worked out by the method of least squares, show that the average error in multiplication is 0·134 per cent. Similar trials with wooden slide rules gave 0·18 and 0·29 per cent. The average error in the computation of co-ordinates with the celluloid slide rule was found to be 0·12 per cent. The errors consequently are inappreciable when the survey is plotted to any of the scales usually employed for colliery plans. On an average, the error in the results obtained with an ordinary wooden slide-rule of the Gravet type may be estimated at 0·2 per cent., or 1 part in 500, and with the celluloid rule, with its excellent graduation, at half that amount. With a little practice the co-ordinates may be found very quickly, and a survey may be plotted more rapidly than with the protractor.

PRODUCTION OF PIG IRON.

CONTENTS.

	PAGE		PAGE
I. Blast Furnace Practice . .	294	III. Blast Furnace Slags . .	315
II. Chemical Composition of Pig Iron	314	IV. Foundry Practice . . .	316

I.—*BLAST FURNACE PRACTICE.*

The Feasibility of Using Cheaper Fuels in the Blast Furnace.—Although the usual type of blast furnace is a most efficient device for smelting and melting purposes, it is not suitable for utilising the cheaper grades of fuel, such as coal-slack and certain gaseous fuels. This problem not only involves the consideration of the furnace as a suitable apparatus, but also embraces the consideration of the chemical and calorific properties of the proposed fuel. In the hearth of the ordinary blast furnace an extremely high temperature is maintained. This extreme temperature is due to the complete combustion of the fuel in the hearth, and before the gases reach the zone of fusion their temperature is reduced by the absorption of carbon 2300° F. In a smelting-furnace the maintenance of this extreme temperature at the hearth becomes useless when it can be reduced without altering the condition or calorific effect of the reducing gases resulting from combustion. This can be accomplished by providing an auxiliary combustion chamber, and passing the gases thence into the hearth and upwards through the stack. By this method the temperature of the hearth is under control, and may be elevated when necessary. Also scaffolding is avoided, since a melting temperature is continuously maintained. Moreover, by this method impurities that may be con-

;ained in the fuel are oxidised before being brought into contact with ;he metal, which seems to prevent their absorption by the latter. By means of a structural device for supporting the burden, Mr. J. T. Wainwright * has worked a furnace of this description. This furnace consisted of a vertical shaft, with an auxiliary combustion chamber leading into the hearth. Above this hearth wrought-iron tubes encircled by fireclay tiles were placed across the shaft to form a support for the furnace charge, with sufficient space between to allow the gases to ascend and permeate the burden, and also to allow molten material to descend into the hearth. These tubes were cooled by a blast of air passing through them, the object being to prevent their being destroyed by the extreme heat in the interior of the furnace. In this furnace natural gas was used as fuel, and it was demonstrated that pig iron could be melted without charging any fuel with the metal, and that ore could be smelted with about 15 per cent. of the amount of coke usefully employed. The feasibility of separating the greater portion of the fuel from the burden having thus been shown, the question suggests itself, why not use a cheap fuel in such a combustion chamber? and what cheap fuels are suitable for this purpose? In answer, it may be urged that a carbonaceous fuel which does not contain too large a proportion of diluents will answer. The usual diluents are combined oxygen, hydrogen, and nitrogen. Hydrogen becomes a diluent in this case because at high temperatures and in the presence of free carbon it will not combine with oxygen. In reviewing the various cheap fuels, it may be remarked that coal-slack is a most desirable fuel for this purpose, since by its use the temperature of the reducing gases would not be greatly lowered. Next in order might be mentioned petroleum, which contains about 84 per cent. carbon, 14 per cent. hydrogen, and 2 per cent. oxygen. In this case the temperature of the reducing gases would be 700° lower than from coke. Natural gas, which contains about 75 per cent. carbon and 25 per cent. hydrogen, would produce reducing gases 1100° lower in temperature than from coke. These deficiencies in temperature, however, may be overcome by means of hot-blast stoves. Carbonic oxide, producer gas, and hydrogen are unfit for this purpose, because they do not contain carbon which is not combined with oxygen.

Anthracite and Coke in the Blast Furnace.—Mr. E. S. Cook †

* *Transactions of the American Institute of Mining Engineers*, vol. xvii.
† *Ibid.*, vol. xvii.

records the results gained by using alternately anthracite and coke, separate and mixed, in the Warwick furnace at Pottstown, Pennsylvania. The furnace in question is 55½ feet high with 15½ feet bosh, and the actual working height from stack line to bottom is only 47½ feet, the bell-and-hopper taking up 8 feet. During the year 1886 mixed fuel was used in the proportion of three-fourths anthracite and one-fourth coke. The total production of iron was 30,629½ tons of 2280 lbs., being a weekly average of 589 tons, including all ordinary and extraordinary stoppages. Deducting the latter, the weekly average would be about 600 tons. The fuel consumption for the year was 1·2 ton per ton of iron, the ore mixture yielding 52 per cent. of iron. For about two months during the summer of 1887 it was necessary to run on anthracite exclusively, owing to the Connellsville coke strike. In the autumn of 1885, in re-lining the furnace, the crucible had been built 8 feet 9 inches in diameter, with the view of using regularly one-quarter of coke (the largest previous diameter having been 7 feet 5 inches). The average of seven weeks' run on coal, as compared with the average of the seven corresponding weeks of 1886 (using one-quarter coke), was as follows :—

Date.	Fuel.	Iron made per Week.	Fuel per Ton of Iron.	Ore.	Limestone per Ton of Iron.
		Tons.	Tons.	Per Cent.	Tons.
1887, seven weeks.	Coal	523	1·262	52	0·7250
1886, seven weeks.	¾ coal, ¼ coke	556	1·278	51·3	0·7125

Date.	Exposure of Stock.	Burden.	Air per Minute.	Pressure.	Temperature of Blast.
	Hours.		Cu. ft.	Lbs.	Deg. F.
1887, seven weeks.	20¾	1 to 1·55	10,907	8·2	938
1886, seven weeks.	18½	1 to 1·55	10,978	7·6	917

A difference of only 33 tons iron per week is shown in favour of mixed fuel; but the poorest work of the blast thus far was made in the summer of 1886. The corresponding weeks of 1888, three-quarters coal and one-quarter coke, show as follows :—

Date.	Fuel.	Iron made per Week.	Fuel per Ton of Iron.	Ore.	Limestone per Ton of Iron.
		Tons.	Tons.	Per Cent.	Ton.
1888, seven weeks .	¾ coal, ¼ coke	634	1·1375	54	0·65

Date.	Exposure of Stock.	Burden.	Air per Minute.	Pressure.	Temperature of Blast.
	Hours.		Cu. ft.	Lbs.	Deg. F.
1888, seven weeks .	17·6	1 to 1·65	11,048	6·4	929

During the autumn of 1887, and until the close of the year, the weekly product (using one-fourth coke) averaged 625 tons; and the year was ended with a total make of 30,660½ tons, just 31 tons in excess of 1886. About the middle of January 1888 Mr. Cook commenced using coke only—a mixture of Connellsville and Clearfield. On account of the difficulty, for want of track and storage-room, of keeping the two varieties separate, the use of Clearfield was soon abandoned, because it was found impossible to fill the furnace uniformly when using the two cokes haphazard, just as they happened to be unloaded. The average results obtained from the use of coke only, from January to March 1888, compared with the corresponding weeks of 1887, using three-fourths coal and one-fourth coke, were as follows :—

Date. (January to March.)	Fuel.	Iron made per Week.	Fuel per Ton of Iron.	Ore.	Limestone per Ton of Iron.
		Tons.	Tons.	Per Cent.	Ton.
1887 . .	¾ coal, ¼ coke	615½	1·15	50·9	0·65
1888 . .	All coke	570	1·22	50·5	0·79

Date.	Exposure of Stock.	Burden.	Air per Minute.	Pressure.	Temperature of Blast.
	Hours.		Cu. ft.	Lbs.	Deg. F.
1887 . . .	17	1 to 1·75	11,118	6·4	944
1888 . . .	14	1 to 1·62	10,485	5·2	934

The quality of iron made was in favour of the mixed fuel, as shown by repeated analyses. The silicon and sulphur in the coke-iron were considerably higher than usual, the phosphorus remaining about the same:—

	Silicon.	Phosphorus.	Sulphur.
Coke iron, average	0·945	0·352	0·101
Mixed fuel iron, average (8 months).	0·588	0·296	0·037

It was found impossible to melt as many tons of ore per week with coke only as they had become accustomed to melt with three-fourths coal and one-fourth coke. The furnace-stack being low (only 47½ feet effective working height), and the coke so much more bulky than coal, the same rate of driving emptied the furnace in from eleven to twelve hours. For several months previous to using coke only, the stock had passed through the furnace in from fourteen to fifteen hours. This seems to be the economical limit, except under temporary favourable conditions. Eleven to twelve hours was found to be too short a period for the economical reduction of the ores, and it became necessary to slacken the speed of the engine and prolong the exposure of the ore to the action of the gases. It was hoped that the coke gases on the smaller weight of ore in the furnace would act more energetically and quickly than the gases from coal, thus permitting a shorter exposure; but in this he was greatly disappointed. The yield of ore mixture and the burden being the same, slower driving was synonymous with reduced output of furnace. As the average burden with coke alone was lower than the burden carried by mixed fuel, the enforced experiment of using coke exclusively was anything but a financial success. With a higher stack the results would have been more favourable. Both as regards yield and economy they had been obtaining maximum results from their little furnace considering the ores used, and they could do no more with coke alone; but, on the contrary, did worse than with three-fourths coal and one-fourth coke. Had they been averaging from 350 to 450 tons iron per week, instead of over 600 tons, and had they then, by using coke, increased the yield to 570 tons per week, no doubt they should have considered the increase very satisfactory, and thought that it partially repaid the extra cost of the coke as compared with the price of coal. From these two trials of all coal and all coke, as compared with a mixture of three-fourths coal and one-fourth coke, it appears, other things being equal, that the latter gives better results in a furnace with comparatively large crucible and low stack than either of the two used alone. The mixture of one-

fourth coke assists in the driving of an anthracite furnace, whilst the coal in a low stack will carry more burden and permit more ore to be melted than will coke alone. Under different conditions, that is, with high stack, all coke, compared with a mixture of the two fuels, would doubtless give better results, especially when the greater difficulties attending the management of an anthracite furnace are taken into consideration. The change from all coke to mixed fuel in March gave rise to irregular workings, the reverse of those experienced in January. The bosh of the furnace, enlarged from the continued use of coke, proved to be too large for a mixture of three-fourths coal and one-fourth coke. There was a constant tendency on the part of the furnace to form new lines to conform to the changed conditions. Instead of filling up slowly, and reducing the area gradually, the disposition was to fill rapidly and too much at once, indicated by casts much too small for the amount of stock filled. This filling, being soft and pasty, would cause stock to settle slowly along the walls, and frequently to stick fast, and occasionally to arch over and refuse to settle at all. For several weeks it was a continuous struggle to keep the furnace in successful operation. The amount of iron made for the month was fairly satisfactory—2605 tons—but the fuel consumption reached 1·204 ton, with ores averaging 51 per cent. Towards the latter part of March the bosh of the furnace got into better shape—better proportioned to the fuel used. Bosh-coils and plates cooled off considerably, the bosh-filling became hardened, wearing smoother, and the stock settled regularly and evenly. Thus April began under favourable conditions, and for that month the best record in the history of the furnace was made, reaching a total of 2792½ tons, an average of 93·8 tons per day, with a 51 per cent. ore mixture and 1·16 ton of fuel per ton of iron. The largest weekly yield was 687½ tons, and the largest daily product 110½ tons. This work was continued through May with a product of 2809½ tons, the fuel consumption being 1·13 ton per ton of iron, and the ores yielding 52·5 per cent. The May product was reduced by about 50 tons, owing to a serious outbreak of iron, setting fire to the casting house and doing other damage, but not sufficient to put the furnace out of blast.

Fine Magnetites in the Blast Furnace.—In response to an inquiry from the editor of the *Journal of the Charcoal Iron Workers*, Mr. E. S. Moffat states that his experience has been chiefly with concentrated Chateaugay (Lake Champlain) ore, and that very little trouble was

experienced with it. Recently the four Scranton blast furnaces, which are in operation, have been treating one-sixth concentrated Chateaugay ore. They have worked just as well as when ordinary furnace ores were used, no increase of pressure, no irregularities, and no trouble of any kind being observed. As an experiment the quantity of concentrated ore in use on No. 1 furnace (73 feet high by 20 feet bosh) was doubled, running it up to one-third of the ore charge. The only other change made was a slight decrease of limestone, the speed of the blowing engines and all other conditions being kept the same as before. Some increase of pressure at the tuyeres was expected, but such has not been the case. The furnace was working well before the change was made, and has worked just as well since. There has been no increase in pressure of blast, no decrease in the number of charges per day, and no irregularities of any kind. The fuel used is one-fifth coke and four-fifths Lakawanna anthracite.

During 1887, No. 5 furnace (70 feet by 19 feet) treated for several weeks 50 per cent. concentrated Chateaugay ore. When this trial was made a considerable increase in pressure of blast was anticipated, and in order to meet this the proportion of coke was increased to one-third. Afterwards it was concluded that this increase of coke was unnecessary, as the pressure of the blast went down considerably. The furnace worked well on 50 per cent. of concentrated ore, and showed no peculiarities. None of the concentrated Chateaugay ore is coarser than what will pass through a $\frac{1}{4}$-inch hole, and most of it very much finer.

Magnetite Ores and Foundry Iron.—In discussing the question, "Why is it difficult to make good foundry pig iron from a burden of all magnetites?" Mr. E. S. Cook * states that good "foundry iron" may be considered a comparative term, for a brand unexcelled for some purposes may be almost worthless for others, and *vice versa*. Within recent years these distinctions are being made with some intelligence and judgment, but there is still room for improvement. Used in a general sense, good foundry iron may be considered soft, open-grained pig iron, best adapted to the greatest variety of foundry work and capable of carrying a large percentage of scrap. For special purposes, equally as good foundry iron can be made from all magnetites as from any other mixture of ores, but as a rule irons made from magnetic ores exclusively will not rank as high as those made from mixtures consisting largely of brown or red hæmatites.

* *Journal of the United States Association of Charcoal Iron Workers*, vol. viii.

The difficulty of producing a large percentage of foundry iron with magnetic ores was more marked with the small anthracite furnaces of former years than with the larger and better equipped plants of more modern construction. The use of a portion of coke has made the management also somewhat easier, and consequently enabled the percentage of foundry iron produced to be increased.

The difficulties attending the production of a large percentage of foundry iron from all magnetic ores are due to several causes. Mention will only be made of the leading ones. Within certain limits, the greater the ease with which the iron of an ore parts with its oxygen the more regularly and rapidly will the furnace perform its work of reduction and melting, and the hotter will be the crucible with the same weight of fuel. That the reduction of magnetic ores proceeds more slowly than that of brown hæmatites or red oxides is probably due as much to their mechanical structure as to any difference in chemical composition. Most of the magnetic ores available in the Schuylkill and Lehigh Valley districts of Pennsylvania are dense, close, and compact. These ores, even when entirely free from sulphur, are more or less difficult to work, especially when charged into the furnace in large pieces or masses, too heavy for one man to conveniently lift into a charging barrow.

The furnace gases experience more or less difficulty in penetrating, breaking up, and deoxidising dense ores, which can be broken down more cheaply with hammers. Open, porous ores, or ores containing much combined water, are quickly and thoroughly permeated. In consequence, with magnetites there is a greater consumption of heat in the lower parts of the furnace, and, from the presence of ore only partially reduced, there is apt to be sudden variations in the temperature of the crucible. One of the conditions requisite for the production of a large proportion of the higher grades of foundry iron is almost absolute uniformity of temperature of the lower parts of the furnace. The crucible and boshes seem to acquire certain shapes or proportions by graphitic accumulations, without which uniform grades of No. 1 and No. 2 x iron can scarcely be made. Time is required to form these accumulations of graphite, &c., but they are quickly and easily disturbed, and the disturbing cause seriously affects the product of foundry iron. The use of magnetic ores exclusively renders these disturbances more frequent and less subject to control, owing to the difficulty of thoroughly deoxidising them before reaching the crucible. With magnetites forming the burden, the rapidity of travel of the stock

in the furnace needs to be very carefully watched and the composition of the slag kept as uniform as possible. Any considerable variation in slag or too rapid or too slow driving (variations that would pass unnoticed with easily reducible ores) are reasonably sure to produce marked changes in the furnace running on dense magnetites. The objections to structure do not hold good so far as the soft earthy magnetic ores are concerned. These ores, on the other hand, usually carry much sulphur, an element which is well known as an unrelenting enemy of foundry irons. When present in the dense class of magnetic ores, it entirely unfits them for the economical production of foundry iron. When thoroughly washed, however, these form fairly good mixtures, as the washing not only removes the sulphur, but also opens the structure of the ores, rendering them porous and easily attacked by the blast furnace gases. Brown hæmatites and red oxides rarely carry sulphur to any considerable extent, which alone is a decided advantage in their favour in competition with magnetic ores.

Soft magnetic ores, free from sulphur, are fairly well adapted for making foundry grades; with these forming a large part of the burden no particular difficulty is experienced in making open-grained iron; this would indicate that the difference in chemical constitution between the magnetite and the red oxide is not responsible for the greater difficulty experienced in reducing the former.

The grain or fracture of foundry iron by which it is graded, does not always indicate how it will work after remelting. The writer has seen large, dark-grained, and evenly-crystallised iron condemned because it ran hard in small thin castings. The fracture of the iron was all that could be desired, and it also had the soft appearance that is familiar to the expert, but difficult to describe. This iron proved hard in small castings, owing to the low percentage of silicon it contained (from 0·6 to 0·8 per cent.), and even when melted, without the addition of any scrap, would form a slight chill or hard shell on the surface of a casting in immediate contact with the mould. Experiments in the pig beds showed that this metal gave from $\frac{1}{16}$-inch to $\frac{1}{8}$-inch chill as tested in Whitney chill cups.

Foundry irons made exclusively of magnetic ores, whether they be close and dense of structure, or of the soft, earthy varieties, are apt to show this tendency more or less; it is this want of uniformity that renders them undesirable for general foundry work, except as mixtures to strengthen the softer or weaker irons. While low silicon in the pig iron is undesirable for foundry grades, yet for forge irons this quality

becomes valuable. Hence, for the best brands of either grade the average consumer of foundry iron will consult his interest in purchasing his standard iron from furnaces making a specialty of this branch of the business, while the mill manager will avoid the forge grades made by the foundry furnaces, and seek his supply of best iron from those blast furnaces making a specialty of mill or grey forge pig iron.

As a rule the gangue of magnetic ores contains but little free quartz or sand, the silicon is usually in combination with alumina, lime, or magnesia, and the slag to this extent is partially made, so that the limestone flux added to the ore charge to produce slag of certain composition combines with the gangue of the ore more readily, and at lower temperatures, than when the gangue is chiefly quartz and sand. In consequence the iron made is less liable to contain silicon.

Other causes affect the percentage of silicon in the pig; but they pertain more to the management of the furnace itself than to the ores smelted. Large furnaces and superheated blast permit of the production of high silicon foundry iron without particularly affecting the economy of the work. The low silicon foundry irons made from magnetic ores give varying results in the foundry, depending upon the knowledge of the foremen of the melting departments; these irons, when also low in phosphorus, require more fuel to melt them and to run them as fluid as irons rich in silicon and phosphorus, but the difference in cost of fuel per pound of iron melted is but trifling. While this fact is known to many founders, others conduct their cupolas without regarding the different requirements of irons of various compositions, and as a result many imperfect castings are charged to the iron used, when the fault really lies in the management of the cupola.

The grading of foundry iron is troublesome and annoying, as conditions altogether independent of chemical composition change the grain or fracture by which the pig iron is graded, bought or sold. Frequent mistakes are made at the furnace by breaking and grading pig iron when too warm. Sample pigs are usually taken from about the middle of each bed of the cast. The pigs should be cold—the temperature of the atmosphere. If only moderately warm the grain will show larger, darker, and more even crystallisation than when broken entirely cold. If a pig is broken warm and then broken again after losing all its heat the first fracture may show No. 1 grade, while the second, even within a few inches of the first, will be only No. 2, or silver grey. All irons do not alter to the same extent; possibly the higher the silicon

and phosphorus the more difference there is in the appearance of the fractures of the same pig broken warm and then cold.

Blast Furnaces at Mont St. Martin.—G. Bresson* gives as a type of blast furnaces suitable for the manufacture of pig iron adapted for use in the basic Bessemer process, the furnaces erected in 1887 at Mont St. Martin. The dimensions of these furnaces are as follows:—

	I.	II.	III.
	ft. in.	ft. in.	ft. in.
Total height	61 6	62 4	65 7
Diameter at throat	13 5	15 1	20 8
Diameter at boshes	21 4	19 8	23 0
Height of boshes above sole	24 6	24 6	31 2
Diameter at hearth, above	10 6	7 10	7 7
,, ,, below	8 1	7 3	7 2
Capacity, cubic feet	13420	12290	15398

Blast Furnaces in the Ural.—C. Frölich,† of Liswa in the Government of Perm, Russia, referring to the blast furnace with free-lying hearth, recently described by Lürmann,‡ states that a furnace of this kind was built by him at Nischni Tagil in the Ural in 1876, and others have since been erected. At these works a magnetite is smelted which yields about 66 per cent. of iron. Its average composition is about as follows:—

Fe_3O_4.	MnO.	Al_2O_3.	MgO.	CaO.	SiO_2.	P.	S.
86·34	0·57	3·57	0·36	0·91	7·87	0·05	traces.

Charcoal is used as fuel. The charcoal diminishes considerably in value when left in the air; thus, birch charcoal, which weighs when fresh 0·15 ton per cubic yard, increases in weight to 0·23 ton per cubic yard, chiefly by the absorption of moisture.

If cold blast is used the ore is smelted without any additions, whilst if hot blast is employed small quantities of lime and sand are added to produce a sufficient quantity of slag. At these works ferro-manganese is produced in considerable quantities, the percentage of manganese varying up to about 80. In a table accompanying the description full details are given of the dimensions, charges, and working results of several of the charcoal blast furnaces in the Ural. The furnaces men-

* *Revue Universelle*, vol. iii. (Series II.) p. 245.
† *Stahl und Eisen*, vol. ix. pp. 99–103.
‡ *Journal of the Iron and Steel Institute*, 1887. No. II. p. 284.

tioned vary in height from 42 feet to 69½ feet. The charcoal consumed in these blast furnaces is rather more than a ton for every ton of No. 1 Bessemer pig iron produced, and somewhat less when grey or mottled iron is being made.

In section some of the furnaces are round and others elliptical, the latter shape appearing to increase the output when ores are being smelted which are difficult to reduce.

An American Charcoal Blast Furnace.—Mr. S. D. Mills,* the manager of the Martel Furnace Company, St. Ignace, Michigan, describes the arrangement of an American charcoal blast furnace. The arrangement and the working of the furnace are described in detail.

Record of a Charcoal Blast Furnace.—While 85 tons of pig iron in 24 hours has been the greatest outturn of a charcoal furnace yet recorded, the Hinkle blast furnace at Ashland, Wisconsin, has made as much as 112 tons in the same time. The furnace stack is 60 feet high and 12 feet in diameter at the boshes. Four casts are made daily, and each cast covers considerably more than half the floor of the casting house. The outturn of this furnace during the month of March 1889 amounted to 3004 tons of pig iron. It is thus evident that at least one charcoal furnace in point of improvement is keeping pace with the coke furnaces. †

Blasting Large Masses of Iron and Steel.—H. Münch ‡ describes in a paper read before the Austrian Society of Engineers and Architects the results of a number of blasts on large masses of iron and steel. The following are the results of some blasts made by J. Trauzl of the Ternitz Steelworks:—

Weight of Metal 220 lbs.	Depth of Hole Drilled.	Dynamite Used.	Cost.
	Inches.	Lb.	
Pig iron . . .	1·14	0·05	5·8d.
Bessemer steel . .	1·06	0·37	23·9d.

Experiments made in breaking up cast iron guns have shown that for

* *The Canadian Mining Review*, vol. viii. pp. 25–40.
† *American Manufacturer*, vol. xliv. No. 15.
‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxvii.; *Beiblatt*, p. 16.

every 0·4 inch of caliber the quantity of dynamite required was 0·22 lb., or 0·2 lb. of dynamite for 100 lbs. of metal.

In 1880 the author had occasion to break up a large "bear" that had formed in No. 1 blast furnace at Schwechat. The upper part consisted of an agglomerate of iron, slag, graphite, and regulus, cylindrical in shape, 8 feet 8 inches in height and 7 feet 3 inches in diameter. The quantity of dynamite used amounted to 7·7 lbs. The lower part of the bear was also cylindrical, and was 2 feet 3½ inches in height by 13 feet 1½ inch in diameter. It consisted of solid tough cast iron. The quantity of dynamite used amounted to 64 lbs., and the total cost of breaking up the bear amounted to £25. The blast yielded 67½ tons of good iron, and the furnace was in no wise damaged.

Important Repairs to a Furnace in Full Blast.—According to M. Clerc,* these repairs were made in the blast furnace No. 1 of the Nonceau-sur-Sambre Company. The refractory masonry in the widest part of the shaft had its thickness reduced by abnormal wear to 3·94 inches from 25·59 inches, which it had when blown-in. As there was an annular space of 25·59 inches between the fire-brick masonry of the in-walls and the exterior masonry, a cast-iron ring, made in segments, was placed on the arches. On this ring a fire-brick lining, 9·45 inches in thickness, was built against the backing, the lining being held by a series of armatures composed of iron bands. The work was effected while the furnace was in full blast, and occupied three weeks.

Blast Furnace Gases.—In a short history† of what has been done towards the recovery of blast furnace gases during the last thirty years, it is shown the Mr. H. Aitken's process, patented in 1874, remained unworked until 1879, when Messrs. Alexander & M'Cosh, of the firm of William Baird of Gartsherrie, put up plant to obtain the oil, tar, and ammonia at their Gartsherrie works. Having successfully worked the process there, they have adopted it at their other works. At Summerlee and Langloan ironworks, the blast furnace gases are being treated principally for their ammonia. At Govan ironworks plant is being erected to obtain the tar, oil, and ammonia; so that

* *Comptes Rendus de la Société de l'Industrie Minérale*, 1889, Jan. 5; *Moniteur des Intérêts Matériels.*

† *The Scotsman*, March 26, 1889.

shortly one-half of the blast furnaces in Scotland will be utilising their blast furnace gases for the production of tar, oil, and ammonia.

The question may be asked, what would be the value of the tar, oil, and ammonia if the whole of the blast furnaces in Scotland were furnished with plant to secure these products?

Assuming that the make of pig iron in Scotland is 1,000,000 tons per annum, and that two tons of coal are required to produce one ton of pig iron, each ton of coal yielding 23 lbs. ammonium sulphate, there results a total production of 20,000 tons of sulphate, which, at the present price of £12 sterling per ton, would be £240,000. When the crude tarry oil is distilled, each ton of coal is found to give a produce of 16 gallons of oil, or, say, a total quantity of 32,000,000 gallons from the 2,000,000 tons of coal used. The present price of this oil is 2d. per gallon, equal to £250,000. In like manner, each ton of coal produces about 160 lbs. of pitch, which, on the like quantity of coal, equals 140,000 tons. The price of this is 12s. per ton at the works—equal to £84,000. This would represent, if all the furnaces in Scotland were securing their tar, oil, and ammonia, a gross production in value of £574,000. It should be stated that after the gases have been deprived of all this ammonia, oil, and pitch, they are still amply sufficient to supply the necessary heat for raising steam and heating the air required for making the pig iron.

The capital required to be expended on plant to secure the above products may be taken at £5000 per furnace, and if a depreciation of 10 per cent. is allowed on this capital expenditure, say £500 a year, and a further sum of £500 is required for wages of the men employed at the tar and ammonia works, there still remains something like half a million pounds to the good; or, rather, that the cost of pig iron would be reduced by this amount, or by a sum of nearly 10s. per ton, compared with what would have been obtained had the tar, oil, and ammonia been allowed to go to waste as formerly.

Naturally there arises this consideration, where a market would be got for such a large quantity of ammonium sulphate, oil, and pitch. On this head there is little to fear, as practically the make of one-half of the blast furnaces is in the market already, and there is also an unlimited and expanding market for ammonium sulphate. There is too an increasing demand for pitch, principally for making briquettes or artificial fuel, and the great extension of lighting by means of lamps, where these oils are used, leaves little room for doubt that the whole of the products would easily be absorbed.

American Blast Furnace Practice.—Mr. W. J. Hudson* compares American and South Staffordshire practice, and gives reasons why the latter does not rival the former. Briefly stated these reasons are that the ore is richer and more easily reducible than Cleveland clay band, that the working lines of American furnaces are more favourable to steady and rapid work, and thirdly that the air is more compressed and is driven into the furnace in greater volume.

In comparing sections of furnaces it is found that English furnaces are wider at the bosh lines, narrower in the hearths, and consequently the boshes are not so steep. American furnaces more nearly approach the cylindrical form, so that the stock more rapidly descends to the fusion zone after reduction has taken place. A certain amount of taper has to be provided to prevent the formation of ring scaffolds from the squeezing outwards of the pasty material in the lower zones. In English practice with the narrower hearths the blast is delivered well into the centre so that the exterior does not get its proper proportion. In American practice the hearth is wide, and is in reasonable proportion to the width of the bosh, which is kept low, so that when the stock reaches the bosh the only solid material remaining is the fuel. The greater heat thus diminishes the tendency to ring scaffolds. The bosh should, therefore, not be too high.

The blast pressure is often 8 to 10 lbs. per square inch, as against our 3 to 4 lbs. Rapid driving does not throw the furnace off its load, owing to its lines, while the English practice with such blast would give a harder grade of iron, and tend to gob, besides wasting fuel.

American furnaces usually work with closed hearths, having tuyeres placed equidistantly all round. A bronze nozzle is provided at the slag outlet, thus saving the cost of repairing and refettling it. The tuyeres are generally placed higher than ours, being on an average five and a half feet above the hearth instead of three or four. This keeps them cleaner from slag, and delivers the blast with less resistance. The tuyeres are also of bronze, and do not burn or drill so much as iron, thus compensating for their extra cost. Cowper or Whitwell stoves are generally used.

The average production of a Cleveland furnace is not more than 550 tons per week, Cumberland furnaces on hæmatite pig iron may reach 900 tons, while South Staffordshire furnaces rarely exceed 300 tons. The author then gives particulars of the Edgar Thomson A, D, and E

* Paper read before the *South Staffordshire Institute of Iron and Steel Works' Managers.* November 24, 1888.

furnaces, the latter of which has produced as much as 1800 tons per week, and of one of the South Chicago furnaces, which averaged 1357 tons per week.

In the discussion the shorter life of the American furnaces was pointed out. Mr. A. E. Tucker approved of the American practice of using several small blowing engines instead of a single colossal one.

The Ensley Blast Furnaces, Alabama.—The largest blast furnace plant in the Southern United States is that of the Ensley Ironworks, near Birmingham. Three furnaces are now in operation. They are each 80 feet in height and 20 feet in diameter at the boshes. The average daily outturn is 125 tons, $\frac{5}{8}$ of a ton of hard ore being mixed with $\frac{3}{8}$ of a ton of soft ore, the partial compositions of which are as follows:—

	Hard Ore.	Soft Ore.
Metallic iron . . .	38·78	48·87
Silica	11·60	21·48
Calcium carbonate . .	29·29	...

The Pratt coal mines, which are adjacent to the furnaces, produce 3600 tons of coal per day, in addition to some 600 or 700 tons of slack, which is made into coke at the mines. The coke ovens number 1000, and more are being erected.

Each blast furnace has four Gordon fire-brick stoves, 65 feet high by 21 feet in diameter. The blast is heated to a temperature of 1500° F.*

The Keystone Ironworks.—A ground-plan of the new foundry and machine shops erected at Kansas City, Mo., by the Keystone Ironworks Company, is published in the *Iron Age*.† When in full blast the works give employment to 400 men.

The Riverside Ironworks.—The blast furnace erected at the Riverside Ironworks, Wheeling, United States, is 75 feet high, 16 feet in diameter at the boshes, and 9 feet at the crucible, the bell being 6 feet in diameter. According to the *Iron Age*‡ the ore used comes

* *Iron Age*, vol. xliii. p. 195. † Vol. xlii. p. 894.
‡ Vol. xlii. p. 659.

from various mines, and the character varies greatly; great care has therefore to be used in charging. To prevent the uneven distribution of the stock arising from the bell moving in an arc in its descent, the arc being dependent on the length of the lever, a roller is introduced to ensure the vertical descent of the bell. This improvement has considerably increased the life of the furnace, one campaign having yielded 100,000 tons of pig iron for a single lining. The furnace is equipped with four Pleyer hot-blast stoves, the temperature of the blast being 900° Fahr. The blast is furnished by a J. P. Morris engine, having a 36-inch steam cylinder, a 7-foot blowing cylinder, and a 6-foot stroke, and by a smaller engine having a 30-inch steam cylinder, a 7-foot blowing cylinder, and a 4-foot stroke, the limit of pressure being 7 lbs. Steam is furnished by five batteries of 40-inch plain cylinder boilers, 52 feet in length, fed by a "doctor." The stack is 170 feet in height and 9 feet in diameter in the clear. The blast furnace has 2 slag tap-holes, the wall at these spots being kept cool by water-pipes.

Hot-Blast Stove.—A new hot-blast stove has been designed by the Swedish engineer, E. Svedberg.* It has the appearance of a horizontal steam-boiler with a number of long pipes, through which pass the waste gases from the blast furnace, and the air for the blast is heated by passing round the pipes, which are eight feet in length. The stove consists of a cylinder cast in eight pieces, and divided in the centre into two divisions by a false bottom, the cast-iron pipes being fastened at the two ends of the cylinder. The masonry is so arranged that the flame or heat from the space in which the gases are consumed is first directed under the cylinder, then passes through the pipes, reunites in the upper flue, and thence passes to a small heater in the chimney. This consists of a small vertical sheet-iron cylinder with a number of pipes, through which the products of combustion are drawn to the chimney. The waste gases from the furnace pass through a pipe provided with a regulating valve into a cast-iron chest placed in front of the combustion chamber. A number of pipes pass from the lid of the chest into the combustion chamber and supply the air necessary for the combustion of the gases.

The cold air for the blast enters from above into the pre-heater, and then passes through a lower pipe into the stove. It leaves the stove at the top and passes to the tuyeres.

With a heating surface of 1881 square feet the stove costs £300.

**Blad för Bergshandteringens Vänner*, 1888, p. 157.

Hollow Pig Patterns.—Mr. B. F. Fackenthal* describes a pig pattern which has been in use at the Durham furnace for about a year. It is made of best flanging iron, No. 13 gauge, three heats being required.

1st, The sheet is bent to a U shape, with one arm longer than the other, by stamping in cast iron forms. 2nd, A flange of about $\frac{3}{4}$ inch is formed at the top of the longer arm towards the inside. 3rd, The longer arm is bent at right angles giving the final D section required, the small flange coming inside the shorter arm to form the longitudinal joint. The end pieces are stamped out and flanged over, and then riveted in position. All the rivets are countersunk and about $1\frac{1}{2}$ inch pitch. The sow end is put in with the flange outwards, thus forming the hand-hole for lifting the pattern from the sand.

These patterns after a year's use show but little wear and keep a good smooth surface. The cost is stated to be 4s. for labour and 3s. for material for each pattern.

The Grading of Pig Iron.—The pig iron manufacturers of the Southern United States have abandoned the method of grading formerly in use. The following table shows the new method as compared with the old: †—

New Grading.	Old Grading.
No. 1 Foundry.	No. 2 Foundry.
No. 2 Foundry.	No. 2½ Foundry.
No. 3 Foundry.	No. 1 Mill.
No. 1 Soft.	Open Bright.
No. 2 Soft.	Close Bright.
Silver Grey.	Silver Grey.
Grey Forge.	No. 2 Mill.
Mottled.	
White.	

Chrome Ferro-Manganese.—Eckardt ‡ pulverises chrome iron ore containing 50 per cent. of chromic oxide, 12 per cent. of ferric oxide, 11 per cent. of alumina, 18 per cent. of magnesia, and 9 per cent. of silica, and mixes it with acid Bessemer slag containing 45 per cent. of silica, 10 per cent. of ferrous oxide, and 45 per cent. of manganous oxide. To the mixture he adds some tar as a binding agent, and moulds the mass into bricks which he smelts in a blast or reverberatory

* *Transactions of the American Institute of Mining Engineers*, vol. xvii.
† *Iron Age*, vol. xlii. p. 498.
‡ *Berg- und Hüttenmännische Zeitung*, vol. xlviii. p. 10.

furnace to an alloy containing 50 per cent. of chromium, 20 per cent. of manganese, and 20 per cent. of iron.

The Cost of Pig Iron.—In an editorial article on this subject the *Iron Age* * points out that the cost comprises: 1. The cost as shown by the furnace books. 2. The extra cost due to contingencies, accidents, interest on supplies, and interest on plant. 3. The cost of selling, including the interest on the unsold stock of pig iron, the interest on sales from the date of sale to the date of payment, the guarantee fund for bad debts, the brokerage, office expenses, and the cost of loading on the railway when the iron is sold f.o.b. at the works.

With regard to the first of these items of cost, beside the actual cost of reduction in the blast furnace each ton of pig iron must bear a portion of the loss due to the necessity for periodical furnace repairs and to the unavoidable mechanical waste of fuel, &c., outside the furnace. This waste of fuel is rarely less than 2½ per cent., and usually reaches about 5 per cent. The cost of periodical furnace repairs, such as re-lining at the end of a campaign, is estimated at 50 cents the ton of pig iron.

The estimated costs of the second and third main items of cost are given as follows:—

2. *Extra Cost, Interest on Plant, and Contingencies:*—

	Dollar per Ton.
Shortages and accidental losses not otherwise accounted for	0·12
Interest on inventory of ore, fuel, and supplies	0·34
Interest on plant	0·54
Total	1·00

3. *Selling Expenses:*—

	Dollar per Ton.
Interest on stock of pig iron	0·34
Interest on sales at 30 days	0·09
Guarantee fund for bad debts	0·27
Brokerage at 1 per cent.	0·17
Office expenses (not at works)	0·06
Loading expenses	0·15
Total	1·08

The business cost of the ton of pig iron in the United States is therefore about 2 dollars above the actual furnace cost.

* Vol. xlii. p. 669.

Cost of a Ton of Pig Iron in the Sequachee Valley.—Mr. W. M. Bowron * gives an estimate of the cost of pig iron made in a blast furnace built in Sequachee Valley, in which local ore and coal are treated, the soft ore necessary being bought.

Hard ore is worth 75 cents per ton, and soft ore can be had for 2·25 dollars per ton delivered. The ore required per ton (2000 lbs.) of iron is :—

	Dollars.
Hard, 2757 lbs., worth	1·034
Soft, 2325 lbs., worth	2·615
Add 10 per cent. for waste	0·365
Ore per ton of iron	4·014

The next item is coke. The cost of mining is 87·3 cents per ton on trucks at the mine. Coked in 11-foot ovens, holding 4 tons of coal, 8000 lbs. of coal give 4600 lbs. of coke; the cost being 1·929 dollar per ton of coke on trucks at the coke ovens. To make a ton of pig iron with this coke takes 2748 lbs. of coke, worth, including waste, 2·122 dollars, or 2·915 dollars per ton of iron, plus the freight for haulage from the colliery to the furnace. The cost of labour is 155·90 dollars on an average make of 85 tons per day, or 1·834 dollars per ton.

To sum up, the cost of making a ton of pig iron is—

	Dollars.
Ore	4·014
Coke	2·915
Labour	1·834
Stores	0·250
	9·013

This cost is less that of bringing the fuel to the furnace, which may be estimated at 25 cents. There only remains to add for repairs and depreciation of plant 10 per cent. on 100,000 dollars invested and 6 per cent. interest. Calculated on 30,000 tons per annum, these are :—

	Dollars.
Depreciation	0·250
Interest	0·150
Brought forward	9·013
Freight	0·250
Total	9·663

As this represents a ton of 2000 lbs., the cost of a ton of 2240 lbs. will be 10·82 dollars.

* *Transactions of the American Institute of Mining Engineers*, vol. xvii.

II.—*CHEMICAL COMPOSITION OF PIG IRON.*

Composition of Ferro-Manganese and Ferro-Silicon.—Mr. T. E. Holgate* gives analyses of spiegels and ferro-manganese ranging from 8 to 88 per cent. of manganese. Above 88 per cent. it is hardly possible to go, as there is then only 4·75 per cent. of iron left, while there is great difficulty in producing the highest grades in the blast furnace and in keeping them after they are made. The carbon appears to rise in percentage with the manganese, but generally decreases as the silicon increases and *vice versâ*. This is most marked in higher grades when silicon does not exceed 2·0 per cent. With very high percentages of silicon the carbon almost disappears. There seems, however, to be no relation between this property and the atomic weights.

Ferro-manganese with a low percentage of carbon can scarcely be produced in the blast furnace unless a large amount of silicon is introduced into the metal. Another process would be to decarburise the ferro-manganese by cementation in hæmatite. The author made some experiments in this direction and found that the carbon was considerably reduced, especially in lower grades of ferro-manganese. Further experiments were however needed.

Sulphur scarcely ever appears in spiegeleisen, whilst all the phosphorus passes into the metal. Ores low in phosphorus generally contain copper, but this to a few tenths does not injure the steel.

Analyses are given of silicon spiegeleisen containing from 10 to 16 per cent. of silicon and from 19 to 25 per cent. of manganese. This is chiefly used for steel castings at certain works. Doubtless metal containing higher percentages of manganese with considerable proportions of silicon could be made if there were any demand. In these alloys the phosphorus exceeds that in spiegeleisen with the same percentage of manganese.

Next the author turns to ferro-silicon, and describes that containing 14 to 16 per cent. as being often very spongy. Any desired metal up to 18 per cent. at least can be produced. The behaviour of the silica produced by solution in acid varies in an interesting manner. The percentage of carbon decreases in the higher grades, but the manganese cannot well be controlled; it however appears to keep out the sulphur, yet the latter element must be carefully watched or else it is likely to

* Paper read before the *South Staffordshire Institute of Iron and Steel Works Managers*, December 15, 1888.

un up to 0·12 or 0·15 per cent. The author gives an analysis of a eculiar sample of pig iron which contains silicon 6·46, sulphur 0·57, arbon 2·47 per cent. It was made under abnormal conditions.

Composition of American Pig Iron.—The No. 1 Dexter iron nanufactured by the Ohio Iron and Steel Company has the following omposition *:—

Iron.	Manganese.	Graphite.	Combined Carbon.	Silicon.	Phosphorus.	Sulphur.
91·52	1·41	3·34	0·08	3·12	0·46	0·02

The following analysis shows the composition of the No. 3 iron nade at the Irondale furnace and used largely for car wheels by the Southern Pacific Railway Company :—

Carbon.	Silicon.	Phosphorus.	Sulphur.	Manganese.
3·51	0·721	0·339	0·019	0·130

The iron contains no vanadium, traces of which are stated by Mr. A. B. Ropes,† engineer of tests to the above-mentioned railway, to be always present in the imported British varieties of foundry iron.

III.—*BLAST FURNACE SLAGS.*

Gehlenite in Slag.—According to Mr. J. S. Diller and Mr. J. E. Whitfield,‡ numerous square prisms of gehlenite occur in furnace slag found near McVille, Armstrong, Pennsylvania. The isotropic square sections are found to be uniaxial and negative. Spherical liquid and rod-like inclusions are numerous. Cleavage lines are not conspicuous. The easy gelatinisation of the mineral in hydrochloric acid, and its difficult fusibility before the blow-pipe readily distinguish it from similar minerals.

Gehlenite has not previously been reported as occurring in the United States. A rare blast furnace slag of the composition of gehlenite from the Almond Ironworks, Falkirk, N.B., was described in 1886 by Mr. H. Bauerman. §

Slag Bricks.—According to J. Gougé, ‖ at the works of the Société

* Pamphlet issued by Messrs. Pickands, Brown & Co., Chicago.
† *Iron Age*, vol. xliii. p. 279.
‡ *American Journal of Science*, vol. xxxvii. p. 220.
§ *Journal of the Iron and Steel Institute*, 1886, p. 88.
‖ *L'écho des Mines et de la Métallurgie*, vol. xiv. No. 13.

Métallurgique de la haute Moselle [at Neuves-Maisons, Meurthe-et-Moselle, France, slag bricks are made in the following manner:—

The blast furnace slag is granulated by running it when molten into a current of cold water. The sand thus produced is mixed with powdered slacked lime, in the proportion of three parts of slag to one of lime. The mixture is moistened, and moulded in a machine, the pressure employed reaching 2133 to 2844 lbs. per square inch. The bricks on leaving the machine are allowed to dry for at least a month. The slag bricks made at these works measure either $8\frac{1}{2}$ by $4\frac{1}{4}$ by 2 inches, or $9\frac{1}{2}$ by $6\frac{1}{4}$ by $2\frac{1}{4}$ inches. The small bricks weigh 5·4 to 5·5 lbs., and the large ones 8·7 to 8·86 lbs. These bricks resist a temperature of 1000° C., and are very regular in shape, the angles being exceedingly sharp. In the district they are in daily use for canals and other public works, for the construction of forts and barracks, for pavements, and for all kinds of building construction, both interior and exterior. They can be employed with perfect security for the construction of chimneys in dwelling-houses.

Slag Paving Stones.—A portion of Broadway, New York, has recently been paved with slag slabs made at Catasauqua, Pennsylvania. The slag flows from the blast furnace into a ladle, from which it is poured into a series of moulds, arranged on an endless converger by which they are taken to air-tight annealing furnaces, the slag slabs being there allowed to cool very gradually. Crushing tests of such slabs, made by the United States Department of Public Works, gave the following results: 9674 lbs., 12,161 lbs., 12,100 lbs., and 11,860 lbs.*

IV.—*FOUNDRY PRACTICE.*

Compressed Air for Blast in Cupola Furnaces.—An important experiment for applying compressed air direct to a cupola furnace for the melting of iron for casting purposes was recently successfully carried out in Birmingham. Hitherto the air has been applied to the cupola through an American patent blower. The air is now applied direct from the pipe through a jet resembling a steam jet. The volume of compressed air used carried with it nearly 150 times its own volume of free atmosphere. The admission and pressure of the air is easily and promptly regulated by the turning of a wheel which opens or

* *Iron Age*, vol. xlii. p. 679.

closes the aperture through which the compressed air is admitted. The makers of this air injector state, that in the melting of five tons of iron they saved one hour and a half in time, and they estimate that an economy of 40 to 50 per cent. will be effected in the cost of the melting. By the application of the air direct to the furnaces, the engine, and, consequently, the engineer, are dispensed with, and the apparatus can be regulated by the man in charge of the cupola, the danger of accident from the use of steam boilers or of the machinery being avoided.*

Ferro-Silicon and the Economy of its Use.—From the effects produced by the extensive use of high silicon irons for many years, and from the discussion of the subject during the past few years, silicon has come to be considered as a softening agent. In the United States, for a considerable time past, many foundrymen have depended upon the irons made from the lean ores of Ohio and Kentucky as softeners to counteract the hardness of irons made from the refractory ores of Lake Superior and northern New York, and the irons of the South; but it has only lately, through the researches of Mr. T. Turner, been generally understood that this softening quality is due to silicon. Upon examining the analyses of Ohio softeners, made from native ores, it will be found that the percentage of silicon runs from 3 to 7 per cent., and that none regularly made previous to 1887 contained more than 7 per cent.

As the process by which silicon accomplishes these desirable results has become better understood, the demand for high silicon iron has increased. In 1887 foreign irons containing as high as 10 per cent. of silicon were imported into the United States. These high silicon irons go under the name of ferro-silicon. As the call for this imported product increased, ferro-silicon containing from 7 to 14 per cent. of silicon, and of a very high grade in other respects, has been produced in America to supply this demand.

The question has naturally arisen whether the use of irons containing such a high percentage of silicon is as economical as when the percentage is lower. This has led Mr. W. J. Keep and Mr. E. Orton† to the experiments and conclusions set forth in their important paper, in which the subject is treated under the following general divisions:

* *Ryland's Iron Trade Circular.*

† *Transactions of the American Institute of Mining Engineers*, vol. xvii. (advance proof pp. 32).

firstly, a comparison of the composition of foreign and American ferro-silicons; secondly, the inquiry whether the silicon in the pig is retained in the iron when remelted; and thirdly, the inquiry whether the silicon in the pig is imparted to other irons during remelting, without loss of silicon.

I. *A Comparison of the Composition of Foreign and American Ferro-Silicon.*—To make this comparison the following examples have been selected :—

"Govan" ferro-silicon, from a Montreal firm, the analysis being published by them (marked *a* in Table I.).

An imported ferro-silicon (221 in Table I.).

The ferro-silicon used by Mr. Turner in making his tests, the analysis being published by him (marked *b* in Table I.).

The only American ferro-silicon with silicon as high as 10 per cent. made regularly is the "Pencost" brand. Nos. 403 and 401 of the table, representing American ferro-silicon, are of this metal.

For purposes of further comparison four analyses are given of two well-known brands of Ohio softeners, namely, "Wellston" (*c* and *d*), and "Globe" (No. 178, and *e*).

TABLE I.

	Number of Test.	Kind of Iron.	Silicon.	Combined Carbon.	Graphitic Carbon.	Manganese.	Phosphorus.	Sulphur.
Ferro-silicons.	*a*	Foreign, "Govan" . .	10·55	1·84	0·52	3·86	0·04	0·03
	221	„ (New York broker)	10·62	...	...	2·32	...	...
	b	„ used by Mr. Turner	9·80	0·69	1·12	1·95	0·21	0·04
	403	American "Pencost" .	12·08	0·06	1·52	0·76	0·48	trace
	401	„ „ .	10·34	0·07	1·92	0·52	0·45	trace
Softeners.	*c*	American "Wellston" .	6·67	...	2·57	...	0·50	trace
	d	„ „ .	5·06	...	...	...	0·75	0·05
	178	„ "Globe" . .	5·89	0·30	2·85	1·00	1·10	0·02
	e	„ „ . .	6·64	...	...	...	0·99	trace

The points which attract attention in this table are :—

1. The large proportion of combined carbon in the foreign irons. If this carbon remains in the combined state after the ferro-silicon is added to the foundry mixture it will tend to harden the resultant

casting. The carbon of the American ferro-silicon is in the graphitic state, to begin with, and therefore such irons should be the superior softeners.

2. Manganese in the foreign irons runs much higher than in the American. It is the general belief that manganese acts more powerfully than silicon, and in an opposite direction, causing carbon to assume the combined stage. If this is the case a large part of the silicon in the foreign irons would be needed to neutralise the effect of their contained manganese, leaving much less silicon to exert a softening influence upon the combined carbon of the hard iron which it is expected to soften, than would be the case if the manganese were absent. In the American silicon-irons the manganese is so low that the silicon is free to act directly on the combined carbon of the iron to which it is added.

3. The foreign irons are nearly free from phosphorus, while "Pencost" contains about one-half of one per cent., and the other American irons which have been mentioned contain about one per cent. In most foundry mixtures, it may be noted, phosphorus will not run below one-half of one per cent., and therefore the effect of the phosphorus, aided by the use of American ferro-silicon, will not affect the mixture. Such a small quantity of these high-silicon irons is needed to produce desired results that, if they contained no phosphorus whatever, their use could not reduce phosphorus in the mixture one-tenth below its former amount. Again, perhaps a small percentage of phosphorus in foundry iron may do more good than harm.

4. The high percentage of silicon contained by these irons, both foreign and American, is noticeable, as compared with the American softeners made in former years. This increase in silicon percentage has led to the name ferro-silicon.

II. *Is the Silicon in the Pig Retained in the Iron when Remelted?*—The high-silicon irons are made in a furnace at a very high temperature, and it has been asserted that when remelted in the foundry, at a much lower temperature, the iron will lose much of its silicon, which will be carried off in the slag.

The introduction of these high-silicon irons has led to a discussion as to the relative value of softeners, with high or low silicon, and also as to the relative economy in the use of a 10 per cent. metal, as compared with an iron in which the silicon reaches only half that percentage.

Seven pigs of "Pencost" ferro-silicon, containing silicon ranging from

4½ to 12 per cent., were secured. These pigs (except the first one) were made at the same furnace and from the same stock, and under the same general conditions, which would insure a similar composition in each, except as to the silicon, and the change in carbon which the variation in silicon would produce.

Sets of test-bars were made from each of these pigs and tested by "Keep's Tests;" the crucible temperature being about the same as that of the foundry cupola. These test-bars were then again remelted and a second series of bars was cast and tested. Both the first melts and the remelts were then analysed, with the results shown in the following table:—

TABLE II.

Silicon in Original Pig of "Pencost" Ferro-Silicon.	Number of Test.	Silicon in Test-Bars, First Melt.	Number of Test.	Silicon in Test-Bars, Second Melt.	Actual Loss of Silicon from First Melt.	Actual Loss of Silicon from Second Melt.	Percentage Loss from First Melt.	Percentage Loss from Second Melt.
4·36	397	4·35	405	4·25	0·01	0·11	0·22	2·52
6·76	398	6·75	406	6·57	0·01	0·18	0·14	2·66
8·09	399	8·07	407	7·99	0·02	0·08	0·24	0·99
9·42	400	9·27	408	9·31	0·15	gain	1·59	...
10·34	401	10·29	409	10·24	0·05	0·05	0·48	0·48
11·64	402	10·83	410	10·76	0·52	0·07	4·58	0·64
12·08	403	11·68	411	11·48	0·40	0·20	3·31	1·71

An examination of these results reveals that on the first melting the irons having less than 10 per cent. of silicon lost on an average 0·55 per cent., while those containing 10 per cent. and over, lost 2·80 per cent. of the silicon held in the pig.

On the second melting the losses are twice as great in the low as in the high percentages. From these observations it is concluded that though the absolute loss is greater in the higher numbers, it is still so small in all cases as to be unworthy of consideration.

To further prove the question, whether irons high in silicon can hold their silicon when melted at lower temperature, a series of pigs, from an Ohio furnace, now out of blast, was tested, and the pigs and bars analysed. These pigs were all made from the same mixture of ores, and represent all the grades of iron made at the furnace. The results appear in the following table:—

TABLE III.

Number of Test.	Grade of Iron.	Silicon in Original Pig.	Silicon in First Melt.	Loss of Silicon.
35	Silvery flaky . .	6·99	6·92	0·07
34	,, ,, . .	6·86	6·80	0·06
33	,, ,, . .	6·82	6·75	0·07
36	,, (open) . .	5·66	5·63	0·03
39	A. 1 foundry . .	5·15	5·20	+0·05
37	B. 1 (hot) . . .	4·66	...	...
38	B. 1 (cold) . . .	4·05	4·00	0·05
40	No. 2 foundry . .	3·64	3·44	0·20
41	No. 1 mill . . .	3·57	3·59	+0·02
42	White	1·97	1·98	+0·01

These tests show great uniformity in the losses of silicon, which are in all cases trifling.

A careful study of these two series of tests of Ohio silicon irons, the silicon ranging from 2 to 7 per cent. in the ordinary softeners, and from 5 to 12 per cent. in the "Pencost" ferro-silicons, or, taking both tables together, from the white iron, made so by low silicon, to the whitish iron produced by an excess of silicon, leads to the conclusions:—

1. That silicon pig iron loses practically none of its silicon in remelting, through being melted at a lower temperature.

2. That there is practically the same actual (not proportional) loss from irons, with comparatively low silicon, as with high silicon, and therefore one is as economical as the other, so far as the silicon is concerned.

With a view to compare the losses in foreign with the losses in American ferro-silicons, the authors give the following results:—

TABLE IV.

Number of Test.	Kind of Iron.	Silicon in Original Pig.	Silicon in First Melt.	Silicon in Second Melt.	Percentage Loss in First Melt.	Percentage Loss in Second Melt.
396	Foreign (New York broker)	16·32	14·47	...	11·33	...
213	,, ,, ,,	11·99	10·84	...	9·60	...
214	,, "Govan" . .	9·85	9·81	...	0·40	...
403	American "Pencost" .	12·08	11·68	11·48	3·31	1·71
401	,, ,, . .	10·34	10·29	10·24	0·48	0·48

These results show distinctly that these foreign irons lose in remelt-

ing more than the American irons with which they are compared. The authors do not endeavour to account for this.

III. *Is the Silicon in the Pig Imparted to other Irons without Loss?*—That is, will ferro-silicon hold its silicon until mixed with irons deficient in silicon; and, for making such mixtures, will high or low silicon iron lose most silicon?

To arrive at conclusions regarding these questions four series of melts were made. Each series was composed of four casts and each cast of six sets of test-bars. For these a white iron base (376), with 0·186 per cent. silicon, and a grey iron base (253), with 1·249 per cent. silicon were used; and for adding silicon the first pig of "Pencost" (397), containing 4·36 per cent. of silicon, and the fifth pig (401), containing 10·34 per cent. silicon. The first series was white (376) and 4·36 per cent. of ferro-silicon (397). The second series was white (376) and 10·34 per cent. of ferro-silicon (401). The third series was grey "FLM" (253) and 4·36 per cent. of ferro-silicon (397). The fourth series was grey "FLM" (253) and 10·34 per cent. of ferro-silicon (401).

The four numbers of each series were to contain respectively 1·5, 2, 2·5, and 3 per cent. of silicon. Having been weighed with great care, they were melted so as to avoid oxidation, and were cast into bars and tested, when each set of bars was analysed, with the results shown by the authors in a table, of which a careful examination reveals the following facts:—

1. Losses in silicon increase as the percentage of silicon in the mixture increases. That is, an iron deficient in silicon can have its silicon raised to 2 per cent. with less loss than if raised to 3 per cent.

2. Losses are slightly higher when using the 10 per cent. than with the 4 per cent. iron; but the losses are so small in all cases that no commercial discrimination can be drawn in favour of one class over another in the matter of economy of silicon. In the extreme case of melting a white iron and a 10 per cent. silicon metal together, to produce a dark soft foundry iron, there was no excessive loss in silicon.

IV. *General Conclusions.*—From the results presented the following general conclusions may be drawn:—

1. Pig irons of any grade may be melted and cast without excessive loss in silicon or excessive change in chemical composition.

2. Ferro-silicons lose in remelting a little more silicon than do the softeners containing less silicon; but the difference is so small that commercial distinction is not possible.

3. In alloying silicon irons with scrap or pig iron deficient in silicon,

the silicon is practically all retained in the mixture, and no economy in silicon results from the use of one class of American silicon iron over another.

4. American ferro-silicon, so far as the authors have investigated, is more economical than the imported, and probably, in most cases, softens to a greater extent.

A brief account appears in *Stahl und Eisen** of a paper on the use of ferro-silicon in foundries, which was read by Jüngst before the German Association of Iron Founders at their Munich meeting. The experiments described were made at the Gleiwitz Works with an Ibrügger cupola, and the results, taken as a whole, showed the addition of silicon to have a favourable effect. The experiments, however, are not yet completed, and the author purposes giving fuller details at a later period.

Examination of Cast Iron.—A casting is made in a cylindrical sand mould 8 inches in diameter, and 23 to 26 feet deep. The iron is run from a casting ladle into the mould after the metal has been skimmed. The quality is determined by the colour and behaviour. If the colour is white, and the metal is covered with colourless flame, the casting is considered satisfactory. If the iron is reddish, and gives crackling sparks, then it is not so good. The casting is then skimmed. If an oxidised crust forms, and breaks from time to time, the metal contains much graphite. The metal most suitable does not give much scum, and has considerable mobility. If the agitation is short, and brown spots form, then the metal is poor in silicon, easily becomes white, is hard, and is only fit for large castings.†

Cast Iron Pipes.—Mr. E. Benedict‡ gives notes of his experience while passing 30,000 tons of cast iron pipes. These include references to the forms, thickness, connections, and strength of the pipes, also to the manufacture, including the casting, dipping, &c., and to the best methods of marking them, and testing, strength, weight, variations in thickness, &c.

The Cost of Making Wheels.—Mr. E. Warne, of Easton, Pennsylvania, states that the cost of making a truck wheel at the Taylor Ironworks, High Bridge, New Jersey, is as follows, the data

* Vol. viii. p. 784.

† *Colliery Guardian*, vol. xlvi. p. 623, translated from *Le Charbon*.

‡ *The Indian Engineer*, vol. vi. pp. 260–261, 276–277, 289–290.

being based on the use of three-fourths charcoal pig iron at 26·5 dolla the ton, and one-fourth old wheels at 19 dollars the ton :—

	Dollars.
Iron	6·16
Melting and core drying	0·20
Sand, moulds and cores, flour and facing . . .	0·15
Foundry labour in moulding and casting . . .	0·85
Outside work, unloading materials	0·10
Repairs, wear and tear, taxes, insurance, motive power, and delivery charges	0·40
Total cost	7·86

Four wheels are made from a ton of metal.

PRODUCTION OF MALLEABLE IRON.

The Husgafvel Direct Reduction Process.—Some further details relating to this process are given by its inventor, Mr. Husgafvel.* He shows that the improvement observed in the recent results obtained in using this process, as compared with those which were obtained formerly, is greatly due to the change in the character of the products, a harder metal being now made in the place of the soft iron blooms that it was at first sought to produce. Added to this, the ore is now finely divided before being charged into the furnace, and the reduction is thus more rapidly effected. The blast, too, is now heated to from 200° to 235° C., instead of the former temperature of from 150° to 190°, and the workmen are better acquainted with the work they have to perform.

The author gives various tables showing the results obtained in the further treatment, rolling, &c., of the blooms produced by this process.

At the Alexandroffsky Steelworks, St. Petersburg, Husgafvel blooms have been used in the open-hearth process employed at this works; analyses of two such blooms showed them to contain :—

	Per Cent.	Per Cent.
Sulphur	0·002	trace
Phosphorus	0·39	0·38

The percentage of carbon was not determined, but is believed to have been considerable, as the percentage of phosphorus in the blooms was about one-half of that existing in the pig iron made from the same ore, whilst if an iron bloom had been produced the percentage would have been reduced to one-third.

The author appends the following results of an examination of the chemical composition of various varieties of the bloom obtained in this process :—

* *Stahl und Eisen*, vol. ix. pp. 35–41, 121–124. :

Number of Sample.	Portion of the Bloom.	Carbon.	Sulphur.	Silicon.
		Per Cent.	Per Cent.	Per Cent.
1	Centre	0·07	0·05	trace
	Side	0·06	0·03	trace
2	Centre	0·05	0·02	0·04
	Side	0·09	0·03	?
3	...	1·50	0·02	0·06
	...	1·22	...	...
4	Centre	0·06	0·03	0·03
	Side	0·19	0·02	0·03
5	Centre	0·01	0·04	...
	Side	0·01	0·02	...
6	Centre	0·01	0·03	0·06
	Side	0·012	0·03	0·02
7	Centre	0·03	0·008	0·03
	Side	0·04	0·01	trace
8	...	0·08	0·03	0·02
9	Centre	0·30	0·01	0·05
	Side	0·14	0·02	0·40
10	Centre	0·11	0·02	0·06
	Side	0·08	0·02	0·21

(1.) Bloom taken to the hammer direct from the furnace; produced with normal working; regular fracture. (2.) Similar material showing an irregular fracture. (3.) Metal produced in a molten condition, the furnace working very hot. (4.) Hammered bloom, granular fracture. (5, 6, 7.) Other samples of blooms. (8.) Bar iron rolled from re-heated blooms. (9 and 10.) Bloom produced with hot working (9), and with normal working (10).

The ore from which these blooms were made was Maloblagodatj magnetite. A number of other partial analyses are given of blooms made from spathic carbonate. These analyses represent the output of the Husgafvel furnace at the Dobriansky Works during the period August 7 to August 20, 1886. Of the 32 analyses made 20 determinations gave the percentage of carbon as less than 0·1, 6 of which showed only 0·01. It must, however, be pointed out that these analyses were not made from the bloom as it came from the furnace, but represent samples which had been reheated and mechanically treated. Further, it is observable that the composition of the central portions of the blooms was different from that of the outer portions; the composition of weld iron, puddled balls, &c., always varies in different parts of the same piece of metal.

With regard to the possible maximum size that may be given to the Husgafvel furnace, the author points out that the furnaces having a capacity of 400 cubic feet, do not represent the maximum size, even when ores are employed which are so hard to reduce as the magnetite

used at the Dobriansky Works. It is intended at two other works to erect furnaces, each of which shall have a capacity of 1000 cubic feet. Increasing the size of the furnaces has been found to diminish the loss of metal in the slag. With regard to the relative loss of metal in the production of malleable iron by the Husgafvel and the puddling processes, the author observes that, placing the loss at 10 per cent. of the metal originally present in the ore in the case of the combined blast furnace and puddling process, it is about 12½ per cent. when rich ores are reduced direct in the Husgafvel furnace, rising to 20 per cent. when poor ores are reduced by this process. The cost of treatment is, however, greatly in favour of the Husgafvel process.

The Husgafvel process has two main subdivisions, (1) that in which impure ores are treated for the production of a metal suitable only for use in the open-hearth, and (2) the treatment of purer ores for the direct reduction of iron of good quality.

The author gives detailed estimates of the cost of erecting works for the Husgafvel process, and he considers that for £2200 a works could be erected which would be capable of turning out 4500 tons of metal annually, from bog iron ores containing 30 per cent. of metallic iron. The cost of producing the ton of blooms, charcoal being used as fuel, is estimated at 25·10 roubles (50s. 2½d.).

O. Mürisier,* the manager of the Alexandroffsky Steelworks at St. Petersburg, publishes some details relating to the use of Husgafvel blooms in the open-hearth furnaces existing at the works of which he is manager. The pig iron used in the experiments had the following percentage composition :—

	No. 1.	No. 2.	No. 3.
Phosphorus	0·80	0·78	0·83
Sulphur	traces	0·013	0·013
Silicon	0·66	0·82	0·76
Manganese	1·65	0·92	0·80

The Husgafvel blooms contained—

	No. 1.	No. 2.
Phosphorus	0·34	0·38
Sulphur	traces	0·012

The percentage of carbon in these blooms varied very considerably, but for the purposes of the charge it was considered to be 0·7. With this material four heats were made in a basic open-hearth. Each

* *Stahl und Eisen*, vol. ix. p. 123.

charge was about 8 tons, the percentage composition being about as follows :—

	Carbon.	Phosphorus.	Silicon.	Manganese.
Charge 1 . . .	2·00	0·56	0·300	0·460
Charge 4 . . .	1·74	0·52	0·236	0·362

The four charges were made up as follows :—

	1.	2.	3.	4.
	Tons.	Tons.	Tons.	Tons.
Pig Iron . . .	3·521	3·767	3·144	2·768
Husgafvel blooms .	4·504	4·258	4·914	5·160
Ferro-manganese . .	0·094	0·094	0·094	0·090
Totals . . .	8·119	8·119	8·152	8·018

The ferro-manganese used contained 60 per cent. of manganese. From these four charges 28·8 tons of good ingots were produced, the loss being about 11½ per cent. of the weight of metal originally charged into the furnace. The charge required about ten hours to complete, a period somewhat longer than that required when ordinary iron scrap was used. The blooms were used in the state in which they came from the Husgafvel furnace. The ingot iron produced was of very good quality, and was rolled into angle and shaped iron for shipbuilding purposes.

Forsberg's Hearth.—In Forsberg's new Swedish or three-tuyere hearth * at Nyby, where scrap and pig iron are occasionally treated for the manufacture of fine plates, the weekly consumption for the hearth is 30 to 31·3 tons of scrap with 18·7 per cent. of loss. The scrap iron is mostly in very small pieces and rusty. The consumption of charcoal is 80 to 106 cubic feet per ton of iron. In fining pig iron the weekly production is 19·2 tons with 12·28 per cent. of loss.

The Blair Direct Reduction Process.—The Coneley Rummill Iron Company have erected a direct reduction works on the Blair system at Brewsters, New York. The plant consists of 20 Blair retorts. The ore used is in the form of concentrates from the Theall mine. This finely divided ore is mixed with ground charcoal, the mixture

* *Jernkontorets Annaler*, vol. xliii. p. 391.

being charged into horizontal cast iron retorts, in each of which is rotated a hollow water-cooled arm provided with plough blades. The retorts are then heated and the reduction is completed in about 3½ hours. The product has hitherto been cooled, mixed with pitch, charged into barrels, and sold in that form to crucible and open-hearth steel manufacturers. It is now intended to ball the product in puddling furnaces; two double-puddling furnaces and a trip hammer are being erected for this purpose.*

Iron-making in Madagascar.—In Madagascar the tools used are either of native manufacture or of British make. The latter are imported chiefly from India. Among the tools of native make, the chief are those of the farmer, the stone-mason, the smith, the carpenter, and the plasterer. Joiners' tools, with the exception of the hammers, are of European make.†

The native tools are made of indigenous iron ore, of which there are important deposits in Ilmerina and in the districts of the Betsileos. Some years ago, M. Laborde, a French engineer, set up at Soatsimanampiovanana a blast furnace which still exists, though no longer in use. In the same district the process of iron-making now employed may be seen. The ore, a brown hæmatite, is extracted from the mine and washed in a neighbouring brook, and is thence transported to the forges about a mile distant. The ore is smelted by a process resembling the Catalan in a sort of crucible, whose longitudinal section has the shape of a pointed arch, the point being at the top. It is 30 to 32 inches in diameter, and 24 to 28 inches high. The crucible is constructed of lumps of hard clay, and is demolished after each operation. The fuel used is charcoal dust burned in the neighbouring forest a couple of miles distant. The ore and the charcoal are placed in the crucible in layers, the charcoal being at the centre and the ore at the circumference, or in alternating layers of ore and charcoal. The charcoal is ignited and the blast applied. The latter is obtained from two hollow tree trunks, in each of which there is a wooden piston. The tuyere is double and has the form of a letter Y. The process lasts 6 to 8 hours. When cold, the crucible is broken and the iron bloom is withdrawn. This is then broken up into pieces of suitable dimensions for forging the tools required. The forge is worked by the same blast as the

* *Iron Age*, vol. xiii. p. 119.

† *L'écho des Mines et de la Métallurgie*, vol. xiv. No. 13; *British Trade Journal*, vol. xxvii. No. 317.

furnace, and consists of a hearth dug in the ground and lined with charcoal. Taking into account the cost of the charcoal and the selling price of the tools at the Tananarive market, the net daily profit of a smith may be estimated at 3d.

Iron-making in Corea.—C. Illing * states that iron ores have been worked in Corea on a small scale since ancient times, and that at the present time good cast iron household utensils are made. Indeed, steel is produced on a small scale; but the time and labour requisite for its production are such as in no way to prevent the importation of European iron and steel.

The author was unfortunately unable to inspect a Corean ironworks in operation. An old abandoned furnace he found, on measuring, to be 8 feet high. At top it had an elliptical section 4½ feet long and 2½ feet wide, whilst at bottom the section was more circular, and measured 15 inches across. The blowing engine was formed of a pit, 8 feet long and 15 inches wide, semi-circular at the bottom. Its walls and floor were rendered air-tight by means of bricks and clay, carefully smoothed. In its centre perpendicular to its longitudinal axis there was a parting wall, and on this was the axis of rotation of a horizontal board fitting closely to the walls. This board was moved up and down like a see-saw by two workmen with their feet, whereby the air was alternately compressed in the two air-tight quadrants of the pit, and a continuous current was produced, which passed through two valves opening outwards into the pipe leading to the furnace. The iron ore was smelted with charcoal as fuel, and with lime as flux, and the white pig iron obtained was cast in clay moulds. Lumps of pig iron, 8 inches in diameter, were converted into malleable iron in small smithy fires, worked with a blast similar to that described, and from this iron, knives, nails, scythes, &c., were made in the same forge.

* *Berg- und Hüttenmännische Zeitung*, vol. xlviii. p. 25.

FORGE AND MILL MACHINERY.

A New Forging Machine.—The National Machinery Company of Tiffin, Ohio, have designed a new form of forging machine, intended for use in heading bolts and rivets, and for other similar work. As in other similar machines there is a gripping mechanism for holding the rod, whilst a plunger acts on the projecting end. A full description of this machine appears in the *Iron Age*,* the arrangement of the mechanism being shown in detail by the aid of six illustrations.

New Power Presses.—Two new power presses are illustrated in the *Iron Age*.† One of these, a punching and shearing press, is provided with an adjustable table, to which the die, or the lower knife, is secured. It has an adjustment in height of 9 inches, which allows of a clear space between table and slide, varying from 4 to 13 inches, thus permitting a large variety of work, for which presses of this kind are rarely adapted.

A New Drawing Press.—A machine of this type, designed by the E. W. Bliss Company of Brooklyn, is arranged with a peculiar system of toggle link-work for operating the blank-holder or pressure-plate, which admits of the intermittent motion required to be obtained from the continuous rotary motion of the main crank-pin. A drawing illustrating this arrangement accompanies the description.‡

The Mason Ingot Manipulator.—At the Bellaire Nailworks, Ohio, a 2-high mill is employed. In the rolling operation the ingot is fed to the rolls by means of tables having driven rollers on which the ingot lies, and by which it is moved backwards and forwards as it is passed to and fro through the rolls. Instead of turning the ingot by hand,

* Vol. xliii. p. 117.
† Vol. xlii. p. 696.
‡ *Iron Age*, vol. xliii. p. 8, two illustrations.

a Mason manipulator is employed. This machine embraces a horizontal shaft extending under the table rollers at right angles with the rolls. On this shaft are placed five to seven arms, each being about 6 feet long. The shaft is revolved by a pinion and rack driven by a hydraulic cylinder. The arms are curved on the upper side, and when revolved the points come up under the ingot and turn it over. A further revolution moves it into the desired position. The length of stroke of the hydraulic cylinder is such as to allow the shaft, with its arms, to make one complete revolution. The arms extend upwards between the rollers. The rack, which is attached to the piston-rod of the hydraulic cylinder, is supported on grooved rollers. The ingot having been placed on the rollers is manipulated in the usual way until it becomes necessary to turn it. The rollers then bring it to a position which will enable it to be moved by the arms; steam or water is let into the cylinder, moving the rack forward and turning the shaft; this causes the arm to catch the piece at its lower corner and turn it over. After turning, if it is desired to move it still further, the rotation is continued in the same manner, and the piece may be moved to any desired position upon the table.*

A Three-Thousand-Ton Shear.—At the Homestead Steelworks, in the neighbourhood of Pittsburgh, a 3000-ton shear is now in use. It is worked by the descent of the upper blade, this being effected by the aid of water at a pressure of 4000 lbs. The blades are of crucible steel, and are double diamond in section. This shear can cut steel 48 inches in width and 24 inches in thickness.†

A Forty-Ton Shear.—This shear is at the works of the Elmira Rolling Mill Company, New York. The base is very heavy, and from this rise four wrought-iron columns each 7 inches square. These support two massive bores which in turn carry the eccentric shaft, and the columns also serve as guides for the shear ram, which carries the upper shear blade, the lower one being fastened to the base. The sides of the ram have adjustable gibbs, which are fitted accurately to the square columns, and serve the purpose of maintaining the perfect alignment of the ram as it moves up and down. The machine is double geared, weighs about 40 tons, and is capable of shearing plates $2\frac{1}{4}$ inches in thickness and 36 inches in width.‡

* *Iron Age*, vol. xlii. p. 423, four illustrations.
† Ibid., vol. xlii. p. 575, three illustrations.
‡ Ibid., vol. xlii. p. 425, with illustrations.

A New Vertical Milling Machine.—A new American vertical milling machine is described in the *Iron Age*.* It is very heavy, and the bed and upright portion are made in one casting, and well braced. The upright portion is cored out and provided with shelves and a door, making a convenient tool closet. The table has an automatic cross feed driven by a belt having four changes of speed. Independent circular and longitudinal feeds are also supplied. The cutter spindle is provided with means of vertical and side adjustment, and the head which carries the spindle is counterbalanced and is raised and lowered by a screw operated by the hand wheel at the side of the machine. A small blower, driven from the countershaft by a round belt, is attached to the machine, and a flexible pipe is connected with it for the purpose of blowing the chips from the work.

The Rolling Mills of the Graz Southern Railway.—In rebuilding these mills, F. Moro † observes that after careful consideration it was deemed advisable to erect a reversing train and not 3-high rolls. The great waste of steam observable in most of the old reversing mills proved on examination to be due solely to faulty construction. The engine and train of rolls that were finally erected are described with the aid of a number of illustrations, and the following table shows the successful results that have been attained with the new mill :—

Description.	Old Mill Rolling Single-Length Rails.	New Mill Rolling Triple-Length Rails.
	Tons.	Tons.
Make of rails in twelve hours . . .	50	100–110
Make of rails per man	3	12
Charge per ton of rails	1·220	1·1120
Coal for heating purposes	0·480	0·410
Coal for steam raising	0·530	0·320

The mill runs only during the day, and of the quantity of coal used per ton of rails, as shown in the above table, the loss entailed by stoppage during the night is found to be as follows :—Total weight of coal used for heating purposes, 0·410 ton ; weight of coal used during day shift, 0·290 ton ; for heating up, 0·040 ton ; for keeping hot during

* Vol. xlii. p. 500.

† *Stahl und Eisen*, vol. ix. pp. 2-8, thirteen illustrations.

night, 0·080 ton. Coal used for steam raising, 0·320 ton; weight of coal used during day shift, 0·270 ton; for keeping hot during night, 0·050 ton. These details show the considerable loss that is involved through keeping the mill idle during the night. The coal used is a poor variety, its calorific power being 5600 calories. This, together with the fact that the ingots are kept at least four hours in the heating furnaces, accounts for the relatively large consumption of fuel.

A New Rail Train at the Edgar Thomson Steelworks.—The new rail train at these works consists practically of the ordinary rail train in three sections, the first five passes being made in one train, and the second five in a second train, to which the first delivers direct. The last finishing pass is made in a third train, which is served by a crane. From the table of the first train the billet passes to the second, and from thence it passes by the aid of driven rollers to the finishing train, the finished rail being carried by driven rollers to the hot-saws. The several trains of rolls and the hot-saws are arranged behind one another on the same axial line. Each train of rolls is driven by a separate engine, and is nearly automatic. The daily capacity of the mill is 1000 tons of finished rails.*

Universal Milling Machines.—The three feeds—vertical, horizontal, and transverse—of the universal milling machine constructed by Messrs. Pedrick & Ayer of Philadelphia are all reversible. They are operated or stopped altogether by a single handle. The reversing device is common to engine lathes, and does away with the crossing of belts. A three-step cone on the spindle belts to a lower cone, the shaft of which runs in a hollow stud and drives, by means of the reversing device referred to above, a shaft running through the base of the column. Bevel gears connect this shaft with the vertical shaft, and the latter by bevel gears with the horizontal shaft in the knee, which communicates in turn with the several screws for the various feeds in the front of the knee by clutch gears. These clutch gears can be engaged or disengaged at will by knurled knobs, giving a vertical or horizontal feed. The platen feed is operated from the upper shaft in the knee by means of a pair of mitre wheels running in a bearing which is a part of the platen slide on the knee. A vertical stud passes upwards to the long screw in the platen, and is connected to it by

* *Iron Age*, vol. xlii. p. 462.

clutch mitre wheels. The screw in the platen is splined, and can be engaged and disengaged by a clutch lever.*

Rolling Mills at Pittsburgh.—Mr. T. Ashton † discusses the finished iron and steel trades of America. The numbers and capacities of rolling mills and their plant are given, and some reference made to the early history of the subject. A brief description of a few of the large works is given to indicate their extent and character. The large 3-high plate mill of the Homestead Works is described with some detail. In connection with the mill are four open-hearth furnaces, and six heating furnaces are arranged round the mill train, all these being heated by natural gas. The large universal mill has four rolls, two horizontal and two vertical, and will take an ingot 48 inches square. The horizontal rolls weigh 11 tons each, and are 32 inches in diameter, and can take a plate 53 inches wide. A table on each side of the mill has twenty rollers. The mill is driven by two pairs of compound reversible engines, one pair for each set of rolls. A vertical shear of 3000-ton power is used for the billets from this mill. The maximum stroke is 30 inches, and width of cut 48 inches. Reference is also made to the use of natural gas.

The Universal Mill at the Homestead Steelworks.—Four illustrations of the 32-inch universal mill erected at the Homestead Steelworks, Pittsburgh, have appeared in the *Iron Age*.‡ The illustrations represent (1) a general plan; (2) an elevation of the horizontal rolls; (3) a side elevation of both sets of rolls; and (4) an elevation of the vertical 20-inch steel rolls. The rolls are capable of very accurate adjustment.

The Rolling Mill at the Homestead Steelworks.—A plan of the slabbing and armour-plate mill recently erected at the Homestead Steelworks of Messrs. Carnegie, Phipps & Co., near Pittsburgh, is given in the *Iron Age*.§ The company did not take possession of the ground on which the new open-hearth plant and rolling mills have been erected until April 26, 1886, and on October 14 of the same year the first open-hearth furnace was in operation.

* *Iron Age*, vol. xliii. p. 88.

† Paper read before the *South Staffordshire Institute of Iron and Steel Works' Managers*, December 15, 1888; *Iron*, vol. xxxiii. p. 271.

‡ Vol. xlii. p. 734.

§ Vol. xlii. p. 657.

The new slabbing and armour-plate mill stands in a building 300 feet in length and 120 feet in breadth, with a 35-foot lean-to boiler house.

The plant consists of eight vertical heating furnaces, each being 6 feet in diameter in the clear, and a circular roof, the ring casting of which is of steel. The two hydraulic charging cranes are of the Aiken type, and have a capacity of 35 tons. The main cylinder is 20 inches in diameter, with 13⅓-foot stroke, the height of the crane from the floor line to the bottom of the chord being 34 feet, whilst the swing has a 20-foot radius. The crane is swung by means of a rack and pinion, the hydraulic cylinder having a 6-foot stroke and an 8-inch diameter. A small hydraulic cylinder at the end of the jib is used to grip the ingots. The slabbing train itself consists of two sets of rolls, one of vertical steel rolls, 20 inches in diameter, driven by a special E. P. Allis reversing engine, 30 by 54 inches, and one pair of horizontal rolls, 32 inches in diameter, and 60 inches in length, driven by a pair of 40 by 54 inch E. P. Allis reversing engines, with power tables. This train has already dealt with ingots 36 by 48 inches, weighing 38,000 pounds, and is capable of handling 25-ton ingots, having the dimensions 48 by 54 inches. The steel table rollers are driven by a 10 by 12 Crane engine.

The slabs are delivered to a table 74 feet in length, the rollers being driven by a separate engine. The slabs are sheared by a 3000-ton shear. A gauge is attached to the shear-table, to admit of the slabs being sheared to exact dimensions without taking any measurements. The shear is served by two pressure pumps, which are the largest of their kind, built by the Southwark Foundry, of Philadelphia. They have each a 65-inch steam cylinder, a 10-inch water cylinder and 8-foot stroke, are worked at a steam pressure of 175 pounds, and are capable of yielding a water pressure of 4000 pounds per square inch. The general hydraulic service of the mill is supplied by two Wilson-Snyder duplex pumps, with 8 by 18 inch plungers, and an accumulator. Steam is furnished by six batteries of boilers, each 44½ inches in diameter and 26½ feet long.

The crane service includes two 35-ton charging cranes, two 16-ton slab cranes, and seven 5-ton slab cranes. Several 5-ton and 16-ton cranes have been erected outside of the building for use in handling and storing slabs.

The plate-train is 3-high, the upper and lower rolls being each 32 inches in diameter and the middle one 24 inches. They are 119 inches

in width. By an arrangement of levers and hydraulic cylinders, one man, seated on a travelling carriage, grips the slab, deposits it within range of the crane, lowers the jib, and works the rack and pin which swing the crane.

In the shear department there are thirteen 5-ton cranes, and eight others were in course of erection at the date of the article.

Horizontal Boring Mill.—A machine of this kind, designed by the E. W. Bliss Company of Brooklyn, is so arranged that holes may be bored parallel to each other in heavy work without resetting the work, and without travelling it during the process of boring.*

A Radial Drilling Machine.—The Putnam Machine Company of Fitchburg, Massachusetts, have designed a drilling machine which has a combination of the two standard systems of driving-belt and gear. The cone has four changes, and the idle pulleys are mounted on eccentrics in such a way that the belt may be tightened without stopping the machine. The back gearing, instead of being at the cone pulley, is placed on the arm, this arrangement not only reducing the parts, but also saving power, as the moving parts and bearings are reduced. The head is moved by a rack and pinion gear, and can be firmly held to the arm at any desired point by means of a friction-clamp operated by a lever. Under the collar of the vertical lifting screw is a bal thrust bearing. In the machine illustrated in the *Iron Age*,† the distance from the face of the column to the end of the arm is 6 feet 2½ inches. The arm has a vertical traverse of 36 inches, and the drilling head has a radial traverse on the arm of 42 inches. The spindle has a range of 16 inches, is counterbalanced, and has a quick return by rack and pinion, which is always in gear; it also has hand and automatic feeds of six changes—three for drilling and three for boring. The portable drilling table is accurately planed on all sides. It has T slots on the top and at the sides, and is formed with a vertical V groove for holding square or cylindrical work. The base plate is 9 feet 8 inches long, 44 inches wide, and 6½ inches thick; it has anchor holes for foundation bolts, T slots, guide hole for boring bars, and is planed both on the top and at the bottom.

Turning and Boring Lathe.—Drawings are published in the *Iron*

* *Iron Age*, vol. xlii. p. 381, five illustrations.
† Vol. xliii. p. 236.

Age,* which represent the side and end elevations, and a plan of a lathe designed by Messrs. Johnson of Philadelphia for the United States Government. The lathe is especially designed for both turning and boring the steel hoops used in the construction of 6-inch breech-loading guns. The material of which each of the principal parts of the lathe is made is indicated on the drawings.

* Vol. xliii. p. 79.

PRODUCTION OF STEEL.

CONTENTS.

	PAGE		PAGE
I. By the Carburisation of Malleable Iron	339	II. The Open-Hearth Process	340
		III. The Bessemer Process	345

I.—*BY THE CARBURISATION OF MALLEABLE IRON.*

New Crucible Steel Blast at Chicago.—The works recently erected by the Chicago Crucible Steel Casting Company possesses four double crucible steel furnaces of twelve pots each, one 8-ton open-hearth steel furnace, and one 3-ton iron cupola, together with a gas-producing plant. The cupola has a capacity of 20 tons in twelve hours.*

Manufacturing Steel from Wrought Iron.—At a small village in the Trichinopoly district, called Venkatanaikanpatti, the following process for the manufacture of steel is in use. Small quantities of iron are enclosed, together with a few pieces of wood and two or three green leaves, in a crucible. A top is luted on, and the crucible is heated in a small charcoal furnace till the iron is melted, which is ascertained by shaking the crucible. After cooling, the pots are broken, and a knob of steel is found. Two sizes of ingots are made, weighing 8 ounces and 10$\frac{3}{4}$ ounces respectively. The crucibles are conical, 5 inches long and 2 inches in diameter at the top, and are made from a mixture of red earth and "paddy husk" charcoal. They are not very refractory, and only last one operation. For the smaller ingot 10 ounces of iron and $\frac{3}{4}$ ounce of wood are used. The iron is a rough description of wrought iron, and is brought from Namakal Taluk of Salem. The furnace is an inverted cone of earthwork, 2 feet both in diameter and in depth. The

* *Iron Age*, vol. xlii. p. 310.

apex opens into an ash-pit. Air is supplied by two men working skin bellows. Each furnace holds twenty-five crucibles, and the operation takes about an hour or an hour and a half. The lids of the crucibles often crack, but this does not appear to interfere with the result. The steel is quite fluid, and can be poured easily, a fact which the heat produced does not seem to warrant. The ingots are reheated and hammered to an oblong shape for sale. The annual output is about 28,000 lbs.*

II.—*THE OPEN-HEARTH PROCESS.*

Chrome Iron Ore Linings in Open-Hearth Furnaces.—Odelstjerna † states that in the summer of 1887 the first experiments with Norwegian chrome iron ores were started at the Trollhätta open-hearth steelworks. The ore was in the form of lumps of, at the maximum, ¼ cubic foot in size, mixed with much small ore and dust. The small quantity of large lumps was used in building up the walls, the small ore and dust being used for the hearth. A mixture of lime with twice its volume of finely divided ore was used as mortar. The taphole was made of chrome ore and tar stamped down. The furnace was very carefully heated up on starting.

The reaction at the boiling stage was very violent, and although a much larger proportion of pig iron was used than was customary, the charge was ready very much sooner than was usual. So violent, indeed, was the boil, that it was not deemed prudent to tap the charge until the metal had become very soft, and even then the metal was scattered in all directions. In the pan, too, although it was capable of holding three times the quantity of metal, the boil still continued to such a degree that the metal boiled over the sides, and the same thing happened in filling the moulds. By careful pouring, however, sound ingots were produced.

The experiments were stopped at the end of a week, because the desire at the Trollhätta works is to produce tool steel, and when chrome ore linings were employed, although 60 to 80 per cent. of pig iron was added, only the soft and, for them, useless varieties of iron could be made.

The lining at the end of the experiments was found to have stood extremely well, and had not been in the least degree attacked either

* *Indian Engineer*, vol. vi. pp. 259-260.
† *Jernkontorets Annaler* vol. xliii., No. 7.

by the metal or the slag. A lump of ore broke away, however, from the hearth from time to time, and, rising through the metal, swam on the surface. Still, the hollows in the hearth caused in this way were very easily repaired. The mixture of tar and ore around the taphole did not stand so well. It cracked, and broke in pieces. It was replaced by a mixture of two parts by volume of chrome ore, and one part of lime containing 0·25 per cent. of silica. This mixture hardened and stood very well.

The next experiments with chrome iron ores were made at the Kolsva works. The boil was not nearly so strong as in the experiments at Trollhätta—in fact, the boil was not markedly greater than when acid lining was used. The chrome ore bed softened, but remained intact. This softening was thought to be due to the presence of serpentine in the ore.

In conclusion, the author observes that no better material can be found for the walls of an open-hearth furnace than chrome iron ore, as it is neither attacked by the slag nor does it fuse away. If, however, it is desired to make the bed of the furnace of chrome iron ore, a suitable method will in the first place have to be found out. In Finland, as well as at the Russian open-hearth steelworks, chrome iron ore beds are no longer employed, as it was found that the larger ore lumps broke away from the material of which the bed was composed and rose through the molten metal, thus causing the bed to wear away rapidly. This breaking away of the larger ore lumps does not take place at once, but only after the furnace has been some time at work. A softening of the hearth has in no case been observed at these Russian and Finnish works.

Batho Furnace.—A new arrangement of the Batho furnace by Mr. Hilton is illustrated in *Industries*.* The principal points are the arrangement of the regenerators and the gas and air ports, and the construction of the hearth with a view to basic working.

Basic Open-Hearth Process.—Mr. B. Talbot describes the furnaces in use at the Castle Works, Salop. The pig iron used contains 2 per cent. of phosphorus, 1 per cent. of silicon, and as much manganese as possible. Furnace cinder pig could not be used. For small manufacturers he recommends the use of several small furnaces in preference

* Vol. vi. p. 283.

to a few larger ones, as the expense of manufacture is about equal, whilst there is considerable difference in the capital required.*

The Basic Steelworks of the Graz Southern Railway.—F. Moro † states that these works were originally started as a rail mill in 1861, puddling furnaces being used. In 1864 the Bessemer process was introduced at the works, and in 1870 the first open hearth was erected. Up to 1878 these two processes were equally used, but since that time only open hearths have been employed. In 1886 the acid-lined furnaces were replaced by basic furnaces, and since March 1887 only basic open-hearth steel has been produced. Three such furnaces are now in use. Each of these takes a 12-ton charge. The gas and air openings are placed above one another, the hearth and roof are made of magnesite, and the remaining portions of the furnace of the best Dinas bricks. As a neutral lining between the acid and basic materials, chrome iron ore was at first used, but this has since been entirely abandoned, and the magnesite is now in direct contact with the acid material. The roof stands about 150 charges, the other parts of the furnace lasting about twice as long—for from 350 to 400 charges. Each charge requires about 5 to 5½ hours to complete. For 1 ton of rail-steel ingots the following is the customary charge :—

	Ton.
White pig iron	0·260
Scrap iron	0·740
Spiegeleisen	0·040
Ferro-manganese and ferro-silicon	0·010
	1·050

The spiegeleisen contains 12 per cent. of manganese.

The introduction of the basic process has proved more satisfactory than was anticipated, for although the cost for furnace repairs, &c., has increased by 50 per cent., the white pig iron now used costs only £2, 18s. 4d. the ton, whilst the grey iron formerly used cost £3, 15s.; the gas coal now used is 30 per cent. as compared with 47 per cent. previously, and the production per man per shift is now 1·24 ton as compared with 0·7 ton. The loss of metal has remained constant at 5 per cent. The quality of the steel produced has improved considerably. The metal withstands heat better, and greater pressure when rolling.

* *Colliery Guardian*, vol. lvi. p. 552; Paper read before the South Staffordshire Institute of Iron and Steel Works' Managers.

† *Stahl und Eisen*, vol. ix. p. 1.

The rolling, too, may be more rapidly performed, which admits of four-length rails (98 feet) being now produced. Further, mechanical tests show that for equal hardness the basic steel is tougher than was the acid metal. The great suitability of the basic process for producing exceedingly soft metal has been fully proved at these works, inasmuch as nails made by the new process are of better quality than those formerly made of iron. Again, the armour-plated turrets made at these works of basic steel showed great toughness and resistance when tested near Vienna in the summer of 1888.

Difficulty was at first experienced with the basic method in producing steel castings. It was not easy to recarburise to a higher percentage of carbon than 0·4, as the basic furnace oxidises so rapidly that a portion of the carbon is lost in the melting down of the spiegeleisen. Success, however, was finally attained by adding the necessary quantity of spiegeleisen in the ladle.

Styrian Open-Hearth Steel.—Mr. F. Kobb and Mr. T. Turner,* in a detailed description of some of the more ancient processes in use in Styria for the production of steel, refer to the Erzberg and to the character of its ore, which is usually basic, and is calcined before use. The ore after calcination is very pure. It is smelted with charcoal in blast furnaces about 36 feet high.

The pig is broken up and refined in an open-hearth charcoal furnace. Details of the hearth and method of work are given. The steel produced is exceedingly pure, and owing to this the ancient expensive processes still survive in some parts of the country.

The Open-Hearth Plant at the Homestead Steelworks, Pittsburgh.—The open-hearth plant comprises four furnaces, two of which are basic furnaces, one of 15 tons capacity, the other having a capacity of 20 tons. The two remaining furnaces have acid linings, the capacity being in either instance 40 tons, the average charge being from 65,000 to 70,000 lbs., although it has reached 88,400 lbs. The furnaces are circular, and are worked with natural gas, the stack being at the back of the furnaces, with chequer-work in the flues for preheating the air. At each side of these flues are other narrow ones for cooling purposes.†

* Paper read before the South Staffordshire Institute of Iron and Steel Works' Managers, February 2.

† *Iron Age*, vol. xlii. p. 657.

The Pencoyd Steelworks, Pennsylvania.—These works are situated at Pencoyd, on the Schuylkill River, and on the line of the Philadelphia and Reading Railway. The plant covers 25 acres, and a ground plan of the works is published in the *Iron Age*.* The works were originally started in 1854 as an ironworks; the steel plant was added in 1886, in which year a 20-ton Richmond-Potts open-hearth was erected. A 12-ton furnace with a circular hearth 8½ feet in diameter has since been added. The 20-ton furnace has since been pulled down, and a new one of the type of the smaller furnace has been erected in its stead. The plant includes sixteen double and one single puddling furnace, and a number of rolling mills, together with a 20-ton hammer.

The Henderson Heating Furnace.—A furnace has recently been erected at M'Keesport, Pennsylvania, by Mr. James Henderson, in which natural gas is used as fuel for heating wrought iron scrap. In the construction of this furnace six 1-inch gas-pipes, which deliver the gas into a large expansion chamber, are placed at one end, the quantity being regulated by valves and a pressure gauge. The gas expands till it fills this chamber, travelling from the entrance, for a distance of several feet, to where it meets the air blast delivered in measured quantity in proportions to produce perfect combustion, through tuyeres placed on each side of the gas channel, delivered diagonally forward to a focus at the entrance to the heating chamber, where combustion takes place. The gas in passing to the air is probably heated to 3000° F. before they meet, whilst cold air is used. It is considered that the effect so produced is greater than when either or both the gas and air are heated by regenerators.

The bed of the heating chamber is 20 feet long, 4 feet 6 inches wide, and a space of 5 feet in the clear intervenes between it and the roof. The flame is from 1½ to 2 feet above the piles of metal on the hearth, and 1 foot from the roof for the whole length of the furnace. Iron charged simultaneously at each of the four doors of the furnace becomes as quickly heated at the uptake as where the combustion takes place. In five minutes 250 lbs. charged at each door is at a welding heat and ready to draw, so that five piles, each of 250 lbs., may be heated every five minutes. By charging at one door, and drawing at the same time from another, a pile may be drawn every minute, amounting to 1440, or 180 tons in twenty-four hours. The economy in fuel is considerable, as the gas issues from four pipes at

* Vol. xlii. p. 966.

3 ounces pressure to six pipes at about 4 ounces pressure, which is one-half to three-quarters of the gas used in the old form of heating furnaces, whilst the output is stated to be seven times greater from a much smaller quantity of gas—some nine to ten times less.¶

Wrought iron exposed on the hearth of this furnace in large lots begins to melt in ten minutes, becoming so soft that it cannot be balled unless water is thrown upon it to cool it. This indicates that the furnace will melt rapidly and be economical for making open-hearth steel. The cost of a furnace would not be over 3000 dollars for a bed 20 feet long and 20 feet wide, to make 20 to 25 tons of open-hearth steel per cast. There are no regenerators, nor is there any heated air used. A small fan blower is placed in the gas-pipe, where there is a possibility of a deficient supply of gas, to exhaust gas from the wells and at the same time to increase the quantity used, if so desired. This fan may be placed on the shaft that carries the fan for measuring the air, and may be driven by the same pulley, and thus the air and gas may be measured automatically. Where scrap iron is to be had in quantity, and natural gas is used, this furnace will increase the output of a works up to 180 tons per day for an outlay not exceeding 2000 dollars. If coal is used to make the gas, the cost will be increased by that of a gas producer.*

Gas Valve.—Jardine and Ferguson's gas reversing valve for Siemens regenerative furnaces consists of an ordinary slide valve as used for engines. It is designed to prevent warping, to keep the passages air-tight, and at the same time to give better and straighter passages for the gas.†

III.—*THE BESSEMER PROCESS.*

The Krupp Steelworks at Essen.—In an historical account of the steelworks at Essen, D. Baedeker ‡ states that in the year 1811 Friedrich Krupp erected a small cast-steel works at Essen. The progress made was at first exceedingly slow, and the works were still in their infancy when their founder died in 1826. In 1832 the works were still so small that only 10 workmen were employed. In 1851 the

* *Iron Age*, vol. xliii. p. 133.

† *Industries*, vol. vi. p. 163.

‡ *Alfred Krupp und die Entwicklung der Gussstahlfabrik in Essen*, &c., by Diedrich Baedeker.

largest cast-steel ingot that had up to that time been produced was exhibited at the Great Exhibition of 1851. It weighed 4½ tons. The progress from this time was so rapid that whilst but 74 workmen were employed in 1848, the works include at the present time 1195 furnaces of various forms; 286 boilers; 92 steam hammers; 21 roll-trains; steam power to the extent of 27,000 horse-power, apart from locomotives and steam cranes; 1724 machine tools of various kinds; and 361 cranes, having a total hoisting power of 3219·7 tons. Some of these cranes are so arranged that they can be made to work together, and so lift weights of 120 tons.

The works consume 2735 tons of coal and coke per day. There are 11 blast furnaces of modern construction. These are all in blast, and produce daily about 600 tons of pig iron. The mines in connection with the works include 534 iron mines in Germany, chiefly in Siegen and Nassau, 31 of which are being worked. These yield 1200 tons of ore a day, a portion of which is sold. Besides these there are other mines situated near Bilbao, and these yield over 400 tons of ore a day. The present output can be largely increased if required. The collieries are two in number, with three shafts, the daily output of coal being about 2100 tons.

The total number of workpeople employed is 20,960. Of these 13,626 are at the steelworks; 55 at the gun-testing works near Meppen; 415 at the steelworks near Annen; 1181 at the blast furnaces; 1792 at the collieries; 3807 at the mines; and 84 on the four steamers employed in carrying ore from Bilbao. These steamers have a total carrying capacity of 6100 tons. The total number of persons dependent on the works for their support is about 74,000.

The Wheeling Steelworks.—These works,* which are situated near Wheeling, Western Virginia, were erected in 1886. The works possess two converters, the ordinary charge of metal being 12,000 lbs. The converters are placed side by side in front of a pit, commanded by a central crane. This crane has a telescopic arrangement by which it receives the iron truck into which the iron is run from three 8-foot cupolas placed at the side of the pit. The converters are thus free from runners and other encumbrances. The crane also receives the steel ladle, and the same telescopic arrangement also enables it to be pushed along a short track connecting the converter-pit with the ingot-pit, this latter being also commanded by a central crane.

* *Iron Age*, vol. xlii. p. 501.

The metal blown contains about 1·4 per cent. of silicon; the ingot metal produced contains from 0·05 to 0·08 per cent. of carbon, and about 0·35 per cent of manganese. The metal is chiefly used for nails, the nail-slab ingots weighing about 4000 lbs., and those for billets about 3000 lbs. The average weekly output is about 2000 tons of ingot metal. The ingots are reheated in two pits, each of which has three holes, and takes four ingots. Producer gas is used throughout the works, except for drying ladles and bottoms, for which purposes natural gas is used; but the reason for this selection is mainly the irregular supply of the latter variety of gas. The reheated ingots are taken to a 36-inch blooming mill, and are rolled into billets or slabs for the use of the adjacent nailworks.

Blowing Engines for Steelworks.—R. M. Daelen* describes various modifications in the construction of piston air-compressors for the most powerful blowing engines used for blast furnaces, worked to a pressure of $1\frac{1}{3}$ atmosphere. On the introduction of the Bessemer process, where the air pressure is increased to two atmospheres, clap-valves packed with felt were found insufficiently tight. For this reason Bessemer introduced strips of indiarubber at both ends of the cylinder, which acted alternately for suction and delivery. In summer, when the heating caused by compression imparts to the air a temperature of 212° F., these indiarubber valves gave trouble from the frequent changes necessary. Metallic valves were then introduced, and were at first packed with leather, but are now left unpacked. Thin copper or wrought iron valves have been found more lasting than cast iron valves. In order to reduce the clearance, which in old types of compressors often reached 7 to 8 per cent. of the volume of the cylinder, the author advocates the use of smaller valves in the place of one large valve. For example, instead of one valve $7\frac{7}{8}$ inches in diameter, four circular openings, each $2\frac{3}{4}$ inches diameter, could be used. The valve area would thus be increased 40 per cent., the passage of the air being consequently less impeded, and the clearance reduced to 1·5 per cent. Formerly the area of the suction valves was $\frac{1}{8}$, and that of the delivery valves $\frac{1}{12}$ of the piston area. It is found necessary, however, to increase the area of the inlet valves to $\frac{1}{6}$ or $\frac{1}{5}$ of the piston area, in order to avoid the pressure of the air falling below the atmospheric pressure.

The author describes the air-compressor of Messrs. Walker Brothers,

* *Zeitschrift des Vereines Deutscher Ingenieure*, vol. xxxiii. p. 20.

Wigan, in which a cast iron delivery and suction valve is arranged in the covers at each end of the cylinder, the valves being controlled by spiral springs. With this arrangement, a valve opening of $\frac{1}{14}$ of the piston area is found sufficient. The author considers valves controlled by the motion of the engine, and valves for allowing the air in the clearance spaces to pass to the other side of the piston, unnecessary complications. All parts of the cylinder, including the piston and hollow piston rod, should be cooled with water, in order to prevent unnecessary expansion of the air, and consequently a slow exhaust. The air should be taken from outside the building by means of water-cooled pipes. The cost of the blast in the Bessemer process is about 2s. 6d. per ton, representing a large proportion of the total cost of production. With regard to the question whether vertical or horizontal machines are preferable, the author is of opinion that vertical engines, being subject to less wear, are more advantageous; but the various parts of the engine, being placed one above the other, are necessarily very high. By using coupled engines with condensation, difficulties arise when one engine is disconnected for repairs.

Dephosphorised Steel.—G. Bresson* discusses at considerable length the mode of manufacture of dephosphorised steel and the use that is made of it. He remarks on the varied influence exerted by phosphorus, manganese, and silicon on iron and steel, pointing out that the deleterious influence of phosphorus is greatly modified by the action of carbon and other impurities simultaneously present. The author discusses the influence of the various impurities in detail, and then proceeds to a consideration of the heat evolved on the combustion of the various impurities present in a bath of iron. Allowance being made for the amount of heat which is carried away from the bath of iron by the various products of combustion, the quantities of useful heat produced by the combustion of one part of each of the elements mentioned are calculated to be as follows:—

Silicon	100
Phosphorus	66
Manganese	21
Sulphur	21
Iron	17
Carbon	14

The author then gives a summary of the attempts made to de-

* *Revue Universelle des Mines*, vol. iii. (Series II.) pp. 134–156, 227–248; vol. iv. pp.

phosphorise iron and iron ore which preceded the introduction of the basic process. Lencauchez, in a discussion at a meeting of the French Society of Civil Engineers in 1875, pointed out that for the preceding twenty-five years lime linings had been used for this purpose in the puddling furnaces of the department of the Moselle. Müller in 1869 employed a magnesia-lined converter, and other experimenters also used basic-lined converters without success, the afterblow never having been attempted. The author, after referring to the preliminary experiments of Messrs. Thomas and Gilchrist which resulted in the basic Bessemer process, passes to a theoretical consideration of the elimination in this process of the various impurities present in the pig iron treated, and then proceeds to enumerate the various known ore deposits the ore of which is adapted for the basic Bessemer process, analyses of the various ores found being also given. With reference to the dimensions of blast furnaces suitable for smelting basic ores, the author gives the dimensions of those erected in 1887 at Mont St. Martin and elsewhere, analyses of the pig iron produced being also given. The author next proceeds to discuss the arrangement of basic Bessemer works and the mode of lining the converters, and then describes in detail the mode of operation.

With regard to the works at which basic steel is produced, the author points out that there are now four works in France at which the basic process has been introduced:—1. Creuzot; 2. Joeuf; 3. Mont St. Martin; 4. Valenciennes. The steelworks at Pagny-sur-Moselle was built for the basic process, but this process has not been employed. Basic converters may possibly now be used at the Pompey works. The total annual production of these works amounts to from 165,000 to 200,000 tons. Various shaped ingots are produced, the total absence of silicon in the steel produced at the Longwy works enabling ingots to be cast 0·165 ton in weight, having the dimensions 4 feet 7 inches in height, 5·9 inches wide at the base, and 4·7 inches at the top.

Basic Slag as Manure.—Mr. C. M. Aikman * discusses the various forms of phosphatic manures, and compares them with basic slag. In Germany, 300,000 tons of basic slag are used annually, of which one-third comes from England and Austria.

The various methods which have been proposed for treating the slag may be classified as follows:—

* Pamphlet published by the *North British Agriculturist.*

1. *Preliminary Preparation of Slag.*—(*a.*) By treating, molten or otherwise, with superheated steam, or cooling when hot with water, to reduce it to small pieces or to a fragile state. (*b.*) Grinding. (*c.*) Treating with water to wash out free lime, or with sugar solution. (*d.*) Roasting in the air or with some oxidising agent.

2. *Solution of the Slag.*—(*a.*) Completely in weak or strong acids (hydrochloric, sulphuric, &c.). (*b.*) Partially, so as to dissolve the phosphates and silicates of lime and leave most of the iron and manganese oxides.

3. *Precipitation.*—Precipitation of the phosphoric acid with lime or iron salts, or processes in which the slag is smelted with charcoal so as to reduce phosphates to phosphides, treated with acid, to produce phosphuretted hydrogen which is burnt to phosphoric acid; and processes in which the slag is fused with soda or potash salts, with or without steam being forced through, so as to form soluble alkaline phosphates.

It is found, however, that the most economical way is to apply the finely ground slag direct to the soil, and on the fineness depends much of the result.

The author quotes the results of Dr. Wagner and others, and indicates the proportions in which it should be applied to the land. He considers that in general the phosphorus in basic slag is half as valuable as that in soluble phosphate; while the lime in it under certain circumstances is of great value.

Mr. T. Morris * also gives a brief account of the basic steel process and the use of basic slag as a fertiliser.

Pulveriser for Basic Slag.—For the comminution of basic slag numerous devices have been proposed, but the mixed particles of steel always give rise to difficulties. A mill for this purpose has recently been designed by Jenisch.† In this mill, the slag is fed-in in lumps twice the size of a fist, and in one hour 10 to 12 cwt. of slag may be reduced to the requisite degree of fineness. In the interior of a rotating drum, running surfaces, partly bored through like sieves, are arranged, and cause a number of balls placed in the drum to deviate from the circular path. Increased power is obtained by the falling of these balls after they have left the running surface.

* *Iron and Steel Trades Journal*, vol. xliv.

† *Berg- und Hüttenmännische Zeitung*, vol. xlviii. p. 150; with drawing.

Comparison of Basic Slag and Superphosphate.—E. Meissl * records a series of experiments conducted in thirty different districts, with a view to comparing the value of basic slag and of superphosphate for agricultural purposes. In addition to the phosphates, the ground received a dressing of ammonium sulphate. The yield produced by the basic slag was higher than that produced by superphosphate. The crops were wheat and rye, hay and oats.

* *Biedermann's Centralblatt für Agrikulturchemie*, 1889, pp. 228–229.

FURTHER TREATMENT OF IRON AND STEEL.

The Williams Process of Making Solid Ingots.—This process* consists in casting the metal in an ingot mould of peculiar form. The mould has a cover attached, and so shaped that a space is left in the centre of the cover, between it and the metal in the mould. This latter is built up, one or more of the sides being readily removable. Each removable side is made concave, the greatest depth being at the centre of the ingot. When the outer surface of the cast ingot has become sufficiently solid, the removable portion of the mould is taken away, and a pressure plate is inserted, having a convex side, which fits into the concave side of the mould, and a flat surface opposed to the convex side of the ingot. The removable side of the mould, together with the pressure plate, is then returned to its original position, and pressure is applied. In this way the still molten central portion of the ingot is forced by the pressure exerted on the convex side to flow into the space left below the heated cover. Very solid ingots are obtained in this manner, the head for supplying the pipe being kept molten below the hot cover. A hydraulic press is used to apply the pressure. The use of this process has reduced the quantity of metal that is cut from the heads of steel ingots at the Disston Steelworks, United States, to 5 per cent. In working this process it is found best to put a slight pressure on the cover, in order to hold it in place; but this is not necessary if the force exerted on the pressure plate is applied gradually.

Tool Steel.—Most frequently the failure of tool steel lies in the hardening or tempering. The appearance of the fracture is in general a good indication, and Messrs. F. Kobb and T. Turner † propose the simple experiment of nicking a bar of the steel, heating one end to

* *Iron Age*, vol. xlii. p. 461.

† Paper read before the South Staffordshire Institute of Iron and Steel Works' Managers, February 2, 1889.

whiteness, and then quenching the whole. The hottest part is the hardest, and by breaking off at the nicks the fracture will be some sort of a guide to the temperature required. The expansion of hardened steel, as shown by its decreased density and by measurement, is well known, and it is this which causes the grain of the metal to open, and sets up serious internal strains. There should never be more carbon present in the steel than is required to give the desired temper, as higher carbon steels are harder to work. For large tools it is also advisable to use a slightly milder steel, on account of the greater difficulty in hardening a large tool uniformly.

In hardening steel tools there should always be a good fire when the tool is introduced, and the blast should be turned off till the tool is nearly at the proper temperature. Forging heat should never be employed, and it is better to anneal tools of difficult shape before hardening. Tools with thin edges or parts should have these cooled at times during the heating, and it is also advisable to air cool before plunging. If certain parts only have to be hardened, the heat should be run down gradually, otherwise such parts are liable to crack off. Large tools should be slowly heated, and, to prevent scale, may be sprinkled with salt or potassium ferro-cyanide. Dies and other delicate tools may be placed in powdered charcoal, or a paste of charcoal, ferro-cyanide, and gelatine, but these devices are liable to alter the carbon, and so the temper.

Damascus Steel.—According to Demmin,* the treatment of steel known as "damaskeening" is no longer practised at Damascus. The metal used is a cast steel, in which a strongly marked figuration is produced by the presence of crystallised graphite, which is rendered evident by the corrosive action of acids. In 1804 Clouth imitated the oriental Damascus steel, and Stodart and Faraday considerably improved the process of manufacture. At the present time artificial polished Damascus steel is largely made in France, whence it is exported to the East. It is also made for gun barrels at Liége, and for swords at Solingen and Passau. There are black, brown, and yellow damaskeenings, which are produced in the following manner:—Several bars of steel of different hardness, or of iron, cast steel, and steel, are welded together, hardened, and formed into sword blades. They are then treated with acids, whereby the harder portions acquire a dark colour, whilst the softer portions remain bright. The figurations

* *Berg- und Hüttenmännische Zeitung*, vol. xlviii. p. 8.

appear wavy, striped, or mosaic-like, according to the manner in which the various bars were hammered together. The finest and most expensive variety is said to be the Liége Renard damaskeening, which is formed of three bars welded together, each of which consists of seventy-two iron and seventy-two steel wires. The gun barrel is formed by smithing this compound bar, which is wound round an iron cylinder placed over a mandril. When finished, the iron cylinder is drilled out.

An imitation of damaskeening, which is used in Liége for cheap sporting guns, is produced by affixing paper printed in lithographic ink on the surface of the finished iron or steel gun barrel, and into this dilute sulphuric acid is poured, which corrodes the portions of the barrel not protected by the ink on the paper. On heating the gun barrel, blue and brown colorations are produced.

Variations in the Thickness of Plates.—A number of detailed measurements have been made at the Krupp Works, and at the Schulz-Knaudt Works, Essen, and also at the works of Grillo, Funke, and Company, Schalke, with a view to ascertain what differences exist in the thickness of the various parts of a rolled plate. The results of the measurements made in the case of each of seventy plates examined are given, and the variations in the thickness are found to be occasionally very considerable.*

Ferro-Manganese.—Sergius Kern † proposes the use of the decarbonising process for the purpose of reducing the carbon in ferro-manganese. The ferro-manganese, high in manganese, is cast from the blast furnace into flat pigs, which should be as thin as possible. These are to be heated in a mixture of three parts of hæmatite and one of lime in cast iron boxes. Several experiments on a small scale have proved to be successful.

Ferro-Aluminium.—A description is given ‡ of the works of the Swiss Metallurgical Company at Neuhausen, in which the Heroult process is used. The melted oxide is directly decomposed by electrolysis, and an alternating current cannot therefore be used as in the Cowles process. The crucible is built up of carbon slabs bound to-

* *Stahl und Eisen*, vol. ix. p. 192.
† *Chemical News*, vol. lix. p. 75.
‡ *Industries*, vol. v. p. 405–407.

gether by wrought iron, and forms one electrode. The other electrode consists of a bundle of carbon slabs, and is generally kept about three millimetres above the surface of the molten liquid. The charge consists of pure alumina and scrap iron or other metal. Charging and tap holes are provided in the furnace. The average yield of contained aluminium in the alloy is 30 grammes per horse-power per hour, and each crucible produces 4 cwt. of contained aluminium per hour, with a working current of about 12,000 amperes and 20 volts.

The Protection of Iron from Rust.—It is stated * that Mr. J. Heald, of the machine works at Crockett, California, has employed for the above purpose a mixture consisting of finely ground white lead and turpentine. No corrosive action or scaling is afterwards found to occur, even when heavy coats of paint are laid on the metal treated with the above mixture. The coating may be painted over in the ordinary manner. It had been noticed that old shipping marks had protected the iron under them, while the surrounding surface had rusted badly.

M. de Meritens † produces a protective coating of magnetic oxide on any iron surface by the electrolysis of water. The article is placed in a bath of water, preferably distilled, heated to 70° or 80° C., and is made the anode. A current only just slightly in excess of that required to decompose the water is passed through for a few hours, and it is found that a strongly adhesive black coating of magnetic oxide is produced, and that the oxide even penetrates the metal slightly. A stronger current must not be used, or the oxide scales off. No preparation is required; even rusty articles may be treated. The coating is a brilliant black, and is very hard; moreover, it is not easily wetted by water.

Corrosion of Iron and Steel.—Professor V. B. Lewes ‡ investigates this point with regard to ships. He is of opinion that rusting is due to the presence of water and carbonic acid. This is much accelerated by heat and galvanic action. All attempts at metallic coatings, such as zinc sheathing or galvanising with zinc, have been failures.

Methods employing non-metallic coatings are divided into five classes, using as follows:—(*a.*) Oil paints. (*b.*) Pitch, asphalt, tar, or waxes.

* *The San Francisco Industry*, 1888.

† *Le Moniteur des Produits Chimiques*, through *Industries*, vol. v. pp. 444-445.

‡ Paper read before the Institute of Naval Architects.

(*c.*) Varnishes, consisting of resins and gums dissolved in volatile solvents. (*d.*) Varnishes containing substances to give them body. (*e.*) Coatings of cement.

The great difficulty is due to the so-called sweating of the iron, due to the moisture deposited on it during rapid cooling. The second class, especially waxes, are least affected by this, but they are likely to contain acid. If they could be applied to the hot plates, the question would be solved. Those in the third and fourth classes are likely to be affected by water, and those in the fifth class have practically been abandoned. For internal coatings, bituminous materials applied hot, or sound paint are preferable, as cement allows the percolation of water, &c., and also the cement is likely to crack. Anti-fouling compositions in general have been failures. Most of them contain copper in one form or another, and only their low price keeps them in the market.

Electric Welding.—In a paper read before the American Society of Mechanical Engineers, Mr. C. J. H. Woodbury * describes a series of tests of electric welds on test pieces, including wrought iron, steel, and other metals. In several cases the bars of wrought iron gave way at the weld, which generally was much enlarged in section. Other samples broke at some distance from the weld with their normal breaking loads Some tests of octagonal steel bars gave way at the joint, others at the end of the enlarged section.

A junction between German silver and steel broke at a load of 40,411 lbs. per square inch. Brass and wrought iron in two examples stood 17,450 and 33,550 lbs. before rupture. In another series of tests better results were obtained. Steel welds were, however, always poor, giving way at 70 per cent. of the breaking strain of the bar, unless they were much upset. The octagonal steel showed two perfect welds out of four samples. Among six samples of wrought iron, five were parallel, three failed at the joints at the full strength of the metal, and two broke two inches away from the joint at rather low strains.

The results are impaired by the increased size of the bars at the welds, but enough evidence is given to show that there may be both good and bad welds.

In order to weld the bars, their ends are held in contact in clamps and the current is passed till the metal is softened, when the clamps are caused to approach, and so upset and weld the metal.

* *Engineering*, vol. xlvi. p. 571.

Pipe-Cutting and Threading Machinery.—Messrs. Curtis and Curtis of Bridgeport, Connecticut, have recently constructed some improved forms of pipe-cutting and threading machines, three illustrations of which appear in the *Iron Age*.* A description of the machines accompanies the illustrations.

Rolling Wire.—R. M. Daelen † discusses the manufacture of rolled wire, and draws attention to the gradual improvement in the process of manufacture that has taken place of recent years. The most important modification of the old process has consisted in the substitution of ingot iron for weld iron. The main improvements in the rolling trains have consisted partly in the adoption of breaking down rolls for the larger sized ingots now in use, and partly also in a considerable increase in speed of the final rolls, in recognition of the fact that it is on the speed of these rolls that the capacity of the roll-train depends. Another important alteration has been the introduction of mechanical arrangements in the place of the manual labour by which it was formerly customary to seize hold of the end of the wire as it came from one pass of the rolls and to transfer it to the next.

The author repeats a description of the Domnarfvet wire rolling mill, which was originally published by Professor J. von Ehrenwerth in his account of the Iron Metallurgy of Sweden, the description being illustrated by drawings. Detailed drawings of the wire mill on the Daelen system, erected in 1888 at the Longwy Steelworks, and illustrations showing other types of wire rolling mills, also accompany the paper.

Wire and Wire Ropes.—Mr. J. Bucknall Smith ‡ describes the history and manufacture of wire and wire ropes at considerable length, with illustrations of various forms of rope-making machinery. Details are given of the sizes of ingots used at various works for rolling into wire rods, and also the speeds of rolling and drawing. Special mention is made of large horizontal rope-closing machines for making long lengths without splices.

A Long Wire Rope.—Mr. J. D. Bascom, of the Broderick and Bascom Rope Company, St. Louis, United States, states that the longest wire rope yet made by his company is 35,400 feet in length. It is 1¼ inch in diameter, and weighs 98,100 lbs. New plant, which

* Vol. xlii. p. 172.

† *Stahl und Eisen*, vol. ix. pp. 177–185.

‡ *The Engineer*, vol. lxvii. pp. 209, 243, 316.

has recently been laid down, enables wire ropes of any size and length up to 100 tons in weight to be produced in one continuous piece, without twisting the individual wires composing the cable.

Nails of Tinned Sheet Iron.—Scraps of tinned iron have long been a waste product, the application of which, for any purpose worthy of the intrinsic value of the metals contained in it, has been an unsolved problem. It is true that scraps of this kind have been cast, but the hardness and granular structure render the metal fit only for use as weights. And, to a slight extent, the tin has been removed by electrolytic processes. But there has not been any definite use of this product as a material manufacture until its recent use in America for nails. Scraps of tinned iron are cut by dies into rectangular bits, with a length of about three times their width. These scraps are then fed from an automatic hopper between dies, where they are squeezed first to square form, like a nail, and then headed. Nails of this kind are well fitted for many purposes, being free from tendency to rust, also light, very rigid, and capable of being driven into the hardest wood without buckling.*

Rails.—In a paper read before the American Institute of Mining Engineers, Mr. Hunt ascribes the unsatisfactory wear of rails nowadays to the form of section and to the want of inspection. In discussing this paper, Mr. C. P. Sandberg † adds, the fast driving of the metallurgical and mechanical processes. As to the section—the thin, wide flanges are difficult to roll without using a soft metal, and accordingly the big heads will not wear. Mr. Sandberg objects to abolishing the drop test as advocated by Mr. Hunt and others. It may be modified to allow greater hardness. Silicon should be introduced to make the ingot sounder and save the tops. Rails should not be accepted as No. 2 quality if not up to standard. The fast driving of the metallurgical processes is accountable for the non-homogeneity of the metal, and the fast driving of the mills does not permit of rolling at low temperatures so as to produce a physical hardening and close grain.

Mr. C. P. Sandberg ‡ relates shortly the history of the Goliath rail and the introduction of this form (with slight modifications) on the

* *Engineering*, vol. xlvii. p. 41.

† *Transactions of the American Institute of Mining Engineers*, vol. xvii.

‡ *Minutes of Proceedings of the Institute of Civil Engineers*, vol. xcv. pp. 354–359.

Belgian State Railway. In America the rails are increasing in weight, but owing to the cost they have not reached the Goliath size, except on the Chignecto Ship Railway, where it is proposed to use flange rails of 110 lbs. per yard. Besides the use of bogies and a larger number of sleepers permits the use of a lighter rail. The chemical hardening of the rail introduces danger in cold straightening. The best method is to curve the rail while hot so that the contraction on cooling straightens it, and any further straightening should be done by hammering the head and not the flange. High carbon steel is also likely to fracture during cold weather, as the author shows by experiments made in Sweden. Double headed rails can be made harder than flange rails as they do not curve on cooling, and so do not require so much straightening; thus experience gained from one section of rail is no criterion as to the composition to be given to another form.

Wide, thin rail flanges certainly ought to be abolished. One case is given where the weight and width of flange was increased, but the metal actually had to be softer to stand the same tests. The difficulty of obtaining good wooden sleepers calls for a larger bearing surface on account of economy. The English method of using chairs gives a good bearing but is expensive. To give the same bearing with a suitable section a flange rail would have to weigh 120 lbs. Metal sleepers have great advantages over the English system, and their use is true economy in hot countries. The other method available is the use of a steel base plate under the rail. It has been stated that there should be nothing between the rail and the sleeper, but the author is of opinion that it is only the defects in the rail itself which are the cause of failure. With base plates a large bearing can be obtained, spikes or fang bolts can be used to secure the rails. The base plates could be tapered if it is necessary to give an inclination to the rail, but in the Belgian and Danish State Railways no inclination is given.

Too light rails and imperfect permanent way are the cause of many accidents on the Continental roads where the speed and weight of trains has so largely been increased, as, for instance, in the recent accident to the Czar's train. Next to the recommendation to use heavier rails, no better remedy for the road would be better than the adoption of the bogie system.

A graphic representation is given, by Mr. F. A. Delano,* of the

* *Transactions of the American Institute of Mining Engineers*, vol. xvii. (Advance proof).

causes and relative magnitude of evils or occasions of failure in steel rails and the consequent importance of the causes of these evils. Thus broken rails, uneven wear, split ends or body, battered ends, too rapid wear, and flow of metal, are referred to one or more of the following causes:—chemical hardness or softness, physical hardness, rail from top of ingot or from a bad ingot, bad joint and insufficient bearing.

In the manufacture the uniformity of material charged into the converter assists the attainment of uniformity in the product. Care in pouring ingots at the proper temperature into warm moulds and the treatment of ingots before rolling have important effects. Increasing the diameter of rail ingots may be a positive injury unless they are rolled more slowly or under greater pressure, besides the top which has to be cut off is larger, and this defect is only compensated for by greater height giving greater soundness. For rapid reduction of ingots the rolls should be larger and should be designed so as to support the metal on all sides. Hot rolling of rails, necessitated by present shapes, produces a rapidly wearing rail, as the metal is loose in structure. A change in the section is thus called for, the bearing surface of the wheel tread must be increased, the physical hardness must be increased by cold rolling, and chemical hardness must be increased, this latter being only possible in a section less liable to internal strains. Rails should be slightly low in the centre and not cambered. At present it is impossible to give the best composition for a rail, as the mechanical details play such an important part. In conclusion, the author suggests that one rail from each thousand tons should be laid aside and used on a piece of track where they would have identical service and could be watched.

Rail sections, designed since 1879, for rails of 65 lbs. per yard and over, generally have been removed after comparatively trifling abrasion, and Mr. F. A. Delano * ascribes the poor wearing properties to the form of section rather than to the material.

The load on the rail may exceed the elastic limit; and to counteract this the bearing surface should be increased and also the elastic limit. In general, the author thinks that form of rail faulty which has a large head, wide thin base and thin web, for the following reasons:—the rails have to be finished at a higher temperature; more manganese has to be used to avoid production of many second-class rails; more cold

* *Transactions of the American Institute of Mining Engineers*, vol. xvii.

straightening is required; more internal strains are produced, thus exaggerating the effect of local impurities and preventing the use of higher carbon steels and more variable composition; it is not economical to provide for abrasion if the rails give way before they are worn out; lastly, defects in the ingot which are generally axial go into the head and not into the web where the metal is better worked.

More bearing is required for the wheel tread, and it would appear to be sufficient if the radius of the rail head were twelve inches. Accordingly the head should be wide and shallow, the web and flanges should be heavy with liberal fillets and fishing angles of liberal slope.

A specification is given for rails. The metal is not to contain more than 0·12 per cent. of phosphorus, it is to be poured into warm moulds without spattering or stop, and to be covered with coke or charcoal dust. The ingot must be freed easily from the mould and must not be laid on its side till the inside is solid; it is preferable to keep and heat them in an erect position. Blooming rolls 40 inches between centres shall not be driven at more than thirty revolutions per minute, and other rolls in like proportion. No metal shall be cut from the butt end, but an amount in pounds equal to the area in inches shall be cut from the top, or more if required. Each rail is to be distinctly marked and to conform to the template within $\frac{1}{32}$ inch of height. The rails are to be cut at right angles and within $\frac{1}{4}$ inch of 30 feet at 60°–75° F. Rails are to be free from waves, camber, and roughness. They are to be finished at such a temperature that not more than 4 inches is allowed for contraction on each 30-foot rail sawed immediately after the finishing pass. A drop test, of one ton falling 10 feet on the rail head mid-way between the supports 3 feet apart, is to be used. If one rail fails, two more must pass the test or the whole heat must be rejected.

Life of Rails.—A report presented by a German Commission, details the results of six years' observations on the durability of various kinds of rails in German, Austrian, Hungarian, Dutch, and Belgian Railways. Several kinds of steel, iron, and composite rails have been reported on, with full details as to gradients, curves, track, place of manufacture, &c. The average life of a steel rail may be reckoned at thirty-five years, presuming that the annual traffic is 343,000 tons, and that the maximum and minimum wear are 0·017 and 0·007 millimetres. With the aid of the statistics given, the life of a rail under definite conditions may approximately be determined.

It must, however, be borne in mind that, before reaching the maximum named, the rail would probably be condemned on account of the roughness of its surface.

Steel Sleeper.—Mr. W. G. Bagnall's sleeper is stamped from a rectangular steel plate. It has longitudinal corrugations thrown up in the mid portion and is wider under the rail seat. A central longitudinal trough, deepening towards the ends for drainage, adds to the strength. The chair jaws are also corrugated on their backs. The ends are turned down to bite into the ballast.*

Iron Ties and Sleepers.—In a paper read before the German Iron and Steel Institute, at their Düsseldorf Meeting, March 1889, Mr. Brauns † gave statistics showing that the use of iron sleepers on the German railways is not only making no progress, but that it is very rapidly diminishing. Since the year 1883–1884 wooden cross-ties have again resumed their pre-eminence. The number of wooden ties and sleepers in use in Prussia in 1883–1884 was 29,996,625, whilst in 1887–1888 the number had increased to 33,460,973. Calculated for the whole of Germany, however, this increase was much slower, the increase in the total number of wooden sleepers and cross-ties in use having been only 299,685. The author of the paper points out that the return to the use of wooden sleepers appears likely to make still greater progress in the future, and that the question is of great moment for the German iron industry, as, to take the case of the Rhenish Westphalian district, the cost of labour alone for the ton of finished iron sleepers amounts to from 35 to 40 shillings, the cost of mining the ore, coal, and lime used being included.

In the discussion which ensued on the reading of the paper, Mr. Vahlkampf made a comparison between the cost of production of iron and of wooden sleepers, showing that the cost of production is actually in favour of the metal sleepers when the value of the worn-out sleepers is taken into consideration.

The Standard Metal Cross-Tie.—The steel tie manufactured by the Standard Metal Tie Company, of New York, is illustrated in the *Iron Age*.‡ The tie carries an oak block at either end, on which the rails rest. No fish-plates are required.

* *The Engineer*, vol. lxvii. p. 329.
† *Stahl und Eisen*, vol. ix., pp. 255–263.
‡ Vol. xliii. p. 84.

The Cost of the Production of Steel Rails.—Mr. J. Schoenhof, the United States Consul, at Tunstall, discusses in a Report to the United States Government,* the relative cost of production of steel rails in England and in America; the data, however, on which the estimates are based are incomplete. The following table gives Mr. Schoenhof's estimate of the cost of producing one ton of Bessemer pig iron in Eastern Pennsylvania and at Middlesbrough :—

	Eastern Pennsylvania.	Middlesbrough.
	Dollars.	Dollars.
Ore	11·00	6·56
Limestone	0·40	0·33
Fuel	4·50	2·55
Labour	1·25	0·79
General expenses	0·12	0·12
Sundries	0·50	0·48
Totals	17·77	10·83

Using the above figures as a basis for his further calculations, Mr. Schoenhof estimates the cost of production of the ton of Bessemer steel rails, at the places mentioned, to be as follows :—

	Middlesbrough.	Eastern Pennsylvania.
	Dollars.	Dollars.
Pig iron	12·38	18·00
Spiegeleisen	1·44	4·00
Fuel	1·26	2·00
Labour	3·07	3·88
Sundries	...	0·50
Totals	18·15	28·38

It is considered that in both these cases the estimated cost is too low.

Guns.—E. Lisbonne † endeavours to explain the bursting of a 34-centimetre gun which occurred on December 13 last. The gun

* Department of State, Special Report, No. 49.

† *The Engineer*, vol. lxvii. p. 117; from *Le Génie Civil.*

blew its breach out, and this is ascribed to the method of inserting the steel tube lining, which is secured by the shrinkage of the body of the gun on to the tube near the muzzle. Details are given of other failures in order to make a comparison, the facts for which are chiefly drawn from a pamphlet by Lieut.-Colonel De la Rocque, published in 1884, and entitled "Étude Historique de la Resistance des Canons Rayés."

Armour Plate Trials.—A trial has been made of solid steel armour plates supplied by Schneider & Co. for the Swedish armour-clad *Gota*.* The plate was 6·5 feet by 4·86 feet, and 9·56 inches thick, and weighed 12,676·6 lbs. A six-inch gun with 35·2 lbs. of brown prismatic powder was used. The shot was of chilled cast iron, weighing 99·2 lbs., and had a mean velocity of 1838 foot seconds. Three shots were fired, and penetrated the plate from 3·4 to 3·8 inches, and bulged the back from 0·2 to 0·3 inches. The second shot started a crack from the first dint to the edge of the plate, and this crack appears to extend right through, but the plate was not further broken. The weight of the plate is 504 lbs. per cubic foot, as compared with 480 lbs. for steel-faced armour.

Armour Trials.—The report of the Permanent Commissioners for Experiments in War Materials † compares the resistance to firing of hammered and tempered steel plates made at Terni and at Creusot respectively. A tabular summary of the experiments since 1876 is given, and also illustrations of some of the plates. The Terni plates seem to have surpassed those made at Creusot.

Bridge Steel.—The ultimate strength of steel for bridges, according to the specifications, is allowed to vary within limits of 8000 lbs. to 10,000 lbs., the lower limit being from 56,000 lbs. to 80,000 lbs. per square inch. The higher grade steel may be used for compression members. Low grades of steel are, however, preferable to wrought iron, and according to Mr. R. W. Hildreth,‡ are preferable to the harder steels for the following reasons. The softer steels are more uniform in quality, more easily worked, and less liable to be injured by the processes to which they are subjected. Flaws of all kinds are less injurious, especially in the forged parts of tension members. Delays are less, because rejections are less. And lastly, a greater unit strain is

* *Engineer*, vol. lxvii. p. 97; *Army and Navy Register*, 1889.
† *Engineer*, vol. lxvi. p. 407.
‡ *School of Mines Quarterly*, vol. ix. pp. 248–255.

not justifiable in hard steels, owing the danger from defects and their relative inability to withstand shock.

A series of tests are given, which were made on some high grade steels, to show the effect in full-size eye-bars of flaws and defects developed in the steel subsequent to rolling. In all cases small size test pieces gave good results, such as would be accepted under any specification, while the eye-bars made from the same melt often broke off short in the head or elsewhere owing to some local defect, and gave results much below those shown by the test pieces. One out of many which could be given shows a perfect correspondence in results. Cold straightening frequently determines the place of fracture, and the appearance of the fracture of many bars was similar to that of a cold straightened bar. Other tests showed that the clamps of the upsetting machine injured the metal; if the clamp marks were removed the results were good.

A similar series of tests is given with eye-bars of softer steel, and in each case the full size and the small tests agree. One eye-bar had several cracks in the eye, but these simply opened up, whilst the bar broke in the body with excellent results.

Every cause tending to make soft steel brittle renders hard steel more so, and as the latter is very liable to fail from any flaw, there is a strong argument for using the softer steels. The harder steels also are more difficult to work; all operations such as straightening, shearing, punching, &c., are liable to crack the metal. Punching shows how the plates vary in uniformity, as one part often yields gradually, whilst another part breaks away sharply.

The writer also gives details of some angle pieces which broke under very slight provocation, such as the sudden straightening of a kink in the hoisting chain dropping the piece some two inches. Yet the metal itself was of good quality. On the other hand, some soft steel angles stood any amount of hammering and punching tests.

In conclusion, steel for bridges with ultimate strength of 56,000 lbs. to 64,000 lbs. per square inch and corresponding ductility, is recommended in preference to any metal above 65,000 lbs. ultimate strength.

The Use of Ingot Iron for Bridges.—In connection with this subject Professor Belelubsky * gives the regulations which have recently been officially issued in Russia relating to the use of ingot iron for bridge-building purposes. The first of these regulations

* *Stahl und Eisen*, vol. viii., pp. 841-844.

states that with the exception of the rivets used, which must be of weld iron, all other portions of a bridge may be made of ingot metal. The percentage of carbon must not, however, exceed 0·10, and that of phosphorus 0·05. The tensile strength may vary from 21·6 tons to 25·4 tons per square inch; the elongation must not be less than 25 per cent. The test pieces used are to have the following dimensions:—length, 7·87 inches; breadth, 1·18 inch. The stress at the limit of elasticity should be about one-half of that at the moment of rupture of the test piece, but it must not be less than 10·79 tons per square inch. The metal must bend double when cold without showing any cracks; it must not in the least degree be capable of being hardened; the metal must not be below a cherry-red heat on leaving the rolls, and must then be carefully annealed; holes must be drilled and not punched; the metal may be sheared in the cold, but must be either annealed afterwards, or the rough edges must be bevelled off. A large number of other details are also given.

It is pointed out that soft ingot iron, suitable for bridge erection purposes, is made in Russia at the Alexandroffsky and the Putiloff Works, St. Petersburg; at the Bjansk Works; at the Warsaw Steel-works; and at the works at Kulebaki, Struve.

Steel for Shipbuilding.—Mr. H. H. West* describes the various methods of making steel, the peculiarities of the different kinds, and the purposes for which each is used. He then describes at length the tests of the material required at Lloyd's, the Board of Trade, the Admiralty, and various underwriters. He also discusses the application of steel to shipbuilding, explaining the different strains produced in a vessel under varying conditions, and gives formulæ and criticisms of different authorities, with his own experiences and conclusions.

Cast-steel Water-jackets.—The use of water-cooled breast-jackets or cinder-tap blocks is a great convenience in lead-smelting, even when siliceous slags are made. If the charges are at all basic it is almost imperative. Jackets of riveted wrought-iron or steel are expensive; those of cast-iron are liable to crack; those of bronze are costly and not durable, being easily penetrated by tapping-bars or destroyed by streams of matte impinging against them. To overcome these objections Mr. R. H. Terhune† introduced at the Hanauer works, in

* Paper read before the Liverpool Engineering Society. Jan. 23.

† *Transactions of the American Institute of Mining Engineers*, vol. xvi

April, 1866, cast-steel jackets, which have been in constant use since that time and are at the present time as good as new.

These jackets were made in Chester, Pennsylvania, at a cost of 5d. per lb. at the works. The metal is $\frac{5}{8}$-inch thick, and the jackets were cored and tapped for $1\frac{1}{2}$-inch bushings, affording two large holes for the removal of dirt and incrustations. The same holes are used for feed- and discharge-water through $\frac{3}{4}$-inch pipe.

It is to be hoped that the successful introduction of cast-steel jackets will lead to their more extended use in all branches of metallurgy where water-cooled surfaces are severely taxed, and where the size and thickness of the castings are not unfavourable to the production of a sound article, impervious to water and of high tensile strength.

PHYSICAL PROPERTIES.

Magnetisation of Iron at High Temperatures.—Dr. J. Hopkinson * has discovered that when the magnetising force is small, the magnetic permeability increases very rapidly up to 727° C., but suddenly falls when the temperature is increased by ten degrees. With larger magnetising forces the rapid fall in permeability when the temperature reaches that point is also very marked.

Magnetisation of Iron in a very strong Field.—The results of recent experiments by Professor J. A. Ewing and Mr. W. Low,† show that no considerable change takes place in the value of the intensity of magnetism in wrought iron when the magnetic force is varied from 2000 to 20,000 C.G.S. units. Throughout this range of force, the intensity of magnetism has a sensibly constant value of about 1700 C.G.S. units, which is to be accepted as the saturation value for wrought iron. The following are the probable values of the intensity of magnetism when saturation is reached:—

	C.G.S. units.
In wrought iron	1700
,, cast iron	1280
,, nickel (with 0·75 per cent. of iron)	515
,, nickel (with 0·56 per cent. of iron)	400
,, cobalt (with 1·66 per cent. of iron)	1300

Hadfield's manganese steel, which is remarkable for its impermeability to magnetic induction, was found to have a constant permeability of 1·4 throughout the range of force applied to it, namely, from 2000 to 10,000 C.G.S. units.

The Volatility and Mobility of Iron Atoms.—Dr. T. Fleitmann ‡ observes that opinions have hitherto differed greatly as to the theory of the welding process. The author has studied closely the welding of iron with nickel. His experiments began with tensile tests of iron and

* *Proceedings of the Royal Society*, vol. xlv. pp. 318-321.
† *Nature*, 1888, p. 165.
‡ *Stahl und Eisen*, vol. ix. pp. 9-12.

ikel bars. They showed that it was not possible to tear the metals art by mechanical means after they had been welded together, and it the union of the atoms of the two metals is so intimate that the t pieces will not break at the weld. When it was found to be im- ssible to separate the metals by mechanical means, chemical agency s employed. These latter experiments led to a practical commercial thod for regaining the nickel from the scrap resulting from the nufacture of nickel-faced iron sheets. When such scrap is treated 50° or 60° C. with dilute sulphuric or hydrochloric acid, the iole of the iron back is dissolved, whilst only 2 or 3 per cent. of the ikel passes into solution, the termination of the solution of the iron ing marked by the cessation of the evolution of hydrogen. The two tals then appear to have been completely separated from each other. hen, however, the residual nickel is submitted to chemical examin- tion, it is found that the percentage of iron it now contains is much eater than it was before the commencement of the welding process. one such case the nickel originally contained 0·9 per cent. of iron, d after having been welded to the iron it contained 3 per cent. of it metal. It appeared from these experiments as if the iron and ikel atoms had really intermingled and chemically combined with e another. Further experiments were therefore instituted in order ascertain to what depth the iron atoms had penetrated into the ikel mass during the welding process. To this end sheets of nickel, ich had been separated from the iron backs in the manner described ove, were treated with successive additions of nitro-hydrochloric d. In this manner successive layers of nickel were dissolved away, d the percentage of iron also dissolved was then determined. The lowing table shows the results of one such experiment:

Layers of Metal.	Weight of Nickel dissolved.	Percentage of Nickel dissolved.	Percentage of Iron in the dissolved Nickel.
	Grammes.		
1.	1·569	7·84	5·31
2.	1·711	8·55	3·99
3.	1·715	8·58	2·44
4.	2·019	10·09	1·53
5.	1·896	9·48	1·00
6.	0·919	4·59	0·89
Totals.	9·829	49·13	...

The nickel originally contained about 0·9 per cent. of iron, and the above table shows that it was necessary to dissolve away about 45 per cent. of the thickness of the nickel sheet before the percentage of the contained iron was brought down to the original figure. As the temperature during the welding never approached within 500° or 600° C. of the melting points of the two metals, the author found it impossible to understand how such an inter-admixture of the iron and nickel atoms could have occurred. Further experiments were therefore made to elucidate this question. Some remarkable and regularly recurring phenomena, which are observed when nickel-plated iron sheets are annealed, led the author to conclude that iron is volatile at a medium red heat, and experiments proved this to be the case. When sheets of nickel are placed between sheets of iron, and the whole heated to redness for some length of time, the nickel increases in weight without the least degree of welding having taken place. A true alloy of iron and nickel is found to have been formed on the surface of the nickel plate. The following table shows the results of some experiments made with a nickel sheet weighing 16·1395 grammes, and which was 0·24 inch in thickness. This plate was heated to redness in an iron muffle for about 64 hours. At the commencement of the experiment it contained about 1·10 per cent. of iron. After the period referred to successive portions were dissolved off the sides of the plate, and the iron contained in these solutions was then determined, the results being as follows:

Layers of metal.	Weight of the dissolved metal.	Weight of the iron present in the solution.	Percentage of iron in the dissolved metal.
	Gramme.	Gramme.	
1.	0·595	0·3236	54·4
2.	0·300	0·0546	18·2
3.	0·792	0·0209	2·7
4.	5·914	0·0620	1·05
5.	1·653	0·0193	1·16

Further experiments showed that, although the iron is very volatile at this temperature, the nickel does not volatise at all. The author is not as yet certain whether this volatility of the iron is due to the presence of traces of salt in the atmosphere in which the metal was heated, or to the action of cyanogen or other gases. That the great power of welding which iron possesses, when compared with other

metals, is due to the volatility of the iron, the author believes to be very probable, and he appends some practical remarks on the welding of the metal.

Crystallisation of Iron.—Mr. T. Morris* describes some causes of the crystallisation of iron, and gives figures to prove that the strength of iron increases up to the sixth working, but that from the sixth to the twelfth its strength gradually declines. As the chief causes of crystallisation, he gives the influence of oxygen in puddling, over-heating, percussion, frost, and silicon. The author considers percussion with regard to railway wheels and axles, rails and chains. He is not able to say that the impact of a cannon ball produces crystallisation. Common scrap iron when worked up again is often crystalline.

At a meeting of the Liverpool Engineering Society, Professor H. S. Hele-Shaw † discussed the question whether there is any fibre or grain in wrought iron, and exhibited a number of samples and views showing that it does exist, and is probably due to portions of the slag remaining in the iron becoming elongated during rolling.

Iron Fibre.—In order to break a bar of iron a channel is cut partly or entirely round it with a chisel or file, the bar is then laid on an anvil and struck smartly. The fracture is crystalline or fibrous according as the channel is entirely or partly round the bar. Mr. J. M. Allen ‡ shows that the fibre is not disturbed by the cold chisel, as the filed channel produces the same effect. Nor has the skin anything to do with it, for the bar may be planed down till the groove is removed, and the bar then simply bends when struck. It appears that the bar breaks at the groove because its inner fibres are not protected at that point by the outer layers as they are elsewhere.

The Microscopic Examination of Iron.—Dr. Wedding § describes the method he now employs for preparing the microscopic sections used by him in examinations of the micro-structure of iron. The microscopic section having been produced in the rough, it is carefully cleaned by the aid of chloroform, alcohol, and ether, but care has to be taken in using ether, as it leads to the formation of rust spots.

* Paper read before the *Liverpool Engineering Society*, April 17, 1889.

† *Iron*, vol. xxxiii., p. 256.

‡ *Lecture before Sibley College. Iron*, vol. xxxiii., p. 185.

§ Paper read before the German Iron and Steel Institute, March 1889; *Stahl und Eisen*, vol. ix., pp. 263–268.

The section is clean when a drop of water will wet the whole of the surface. The section thus prepared is next etched. The only solution which has been found by the author to be suitable for this purpose is a mixture of 1 part by volume of hydrochloric acid with 1000 parts of water. Nitric acid is unsuitable, as the different forms of carbon are differently attacked by it. The section after etching is then tempered. The internal changes which occur when a piece of iron or steel is heated, have been shown by Osmond and Werth, Pionchon, and Brinnell, to take place even at the temperature at which the first colours show themselves on tempering—at 210° C. At this temperature a change in the crystalline structure of the metal becomes observable.

The author has found that when a specimen of iron, almost free from carbon—0·05—is heated in an air bath, the temperature of the metal rises gradually and regularly to 210° C. When, however, instead of the soft iron or annealed steel, a sample of hardened steel, containing, say, 1·10 per cent. of carbon, is heated as above, the temperature rises gradually to 105° or 106° C,* and then the rise becomes suddenly slower, sometimes about a third of what it had been at lower temperatures, but when 195° or 196° * is reached the rise of temperature becomes suddenly much more rapid, twice as rapid in fact as it was at the early stage, and then at about 210°—a temperature which varies with the variety of iron under examination—the yellow coloration of the metal appears. This sudden acceleration of the rate at which the metal became hot, the author considers to be due to a change in the state of the carbon. If the metal is rapidly cooled this change or state of the carbon does not take place, but it does if the metal is cooled slowly, and a microscopic examination may therefore prove useful in practice when considering the mode of cooling employed. After much trouble the author has succeeded in producing a photographic arrangement, described in his paper, by the aid of which very clear photographs may be readily produced.

Spectroscopy.—Mr. J. Parry, in a series of articles, gives instructions for the use of the spectroscope and spectroscopic apparatus with details for the mapping and photography of spectra. Considerable space is devoted to the spectroscopy of iron and of manganese in spiegeleisen, with regard to the number, position, and behaviour of the lines, and the indications of other metals given in their spectra.†

* These temperatures are reversed in *Stahl und Eisen*.

† *Industries*, vol. v., pp. 172, 210, 309, 533, 543.

Steel and its Uses.—At the Scranton meeting of the American Society of Mechanical Engineers, the following question was discussed at considerable length:—"What experiences and phenomena can you describe as to the conduct of steels under the conditions in which you were using them?"

Mr. W. W. Dingee stated that the J. I. Case Threshing Machine Company uses large quantities of machinery steel in the manufacture of threshing cylinder teeth. It is found that the texture of such steel is very uneven, and it is not uncommon to find a bar that may be broken like cast steel, whilst at a short distance from the point of fracture it may be bent cold. It is not possible to harden such steel with any certainty by the methods commonly employed.

Mr. W. Kent exhibited some samples of trusses for torsion balances, with spring-steel wires stretched upon them, that had been under test for some months in the factory of the Springer Torsion Balance Company. The longest of three wires on the double truss had been twisted through an angle of 45°—that is, $22\frac{1}{2}°$ each side of its normal position—7,100,000 times. The two shorter wires on the single trusses had been twisted through an angle of 16° 2,200,000 times. The wires were stretched originally to the notes C sharp and D above the staff respectively. After they had been twisted 1,000,000 times each, the tone was tried again, and one of the wires appeared to be half a semitone higher, and the other was about half a semitone lower than when the test was begun, possibly a mistake in the original tuning. After they had been twisted 2,000,000 times each, the tone was found to be same as it was after 1,000,000 twists.

A fractured drill was exhibited by Mr. G. R. Stetson. The drill broke about one inch from the shoulder, the fracture occurring during the night, the drill not being in use at the time, although it previously withstood rough handling. The fracture was believed to be due to irregularity in the hardening.

Referring to the strains induced by working the metal, Mr. C. L. Houston observed that some years ago a $\frac{5}{8}$ plate of American basic steel was sent to a locomotive works to be tested as regards its flanging quality. It was flanged into a locomotive throat sheet, the edges being first turned down, and then the concave end worked out. The next morning a crack appeared at the opposite end, which had not been heated, and had had the roughness of shearing removed by planing. This crack continued to extend gradually for several days, until it reached the whole way across to the part that had been heated.

This crack was due to the contracting strain at the flanged end. The sides of the crack showed no evidence of having been reduced or stretched at the point of fracture. A test piece was cut from one side of the crack, nearly across the grain of rolling, and was so prepared that when tested for tensile strength it had the crystalline face of the crack for one edge of the test piece. The tensile strength proved to be 30·06 tons; the reduction of area was 42 per cent.; and the fracture was fibrous.

In the course of the discussion, Mr. C. T. Main instanced a case in which it had been found necessary to replace steel shafts by iron ones, as the steel shafts broke one after the other, whilst the iron shafts by which they were replaced have stood the strains admirably.

Strength of Wire.—A. Martens * publishes the results of a series of tests of the strength of welded wire-ropes and wire. With new ropes, not previously loaded, every increase of stress was found to produce a small permanent extension. On repeating the tests, this did not occur again; but the extensions were almost exactly proportional to the loads. When at the second test the load exceeded the maximum previously attained, a permanent set was observed. In test-pieces, in which welds were distributed over a length of 20 inches, there was no appreciable diminution of the strength as compared with test-pieces without welds, even when one-sixth of all the wires were welded in one section. In ropes, however, in which the welds were all in one place, the strength was reduced by 33 per cent. The form of the weld has a considerable influence on the strength of the wire, the strength being generally in proportion to the length of the weld.

A. Paalow and Dr. H. Wedding † have made a series of investigations of the connection existing between the conductivity and chemical composition of iron and steel. The results show that the proportion of carbon alone has no influence on the conductivity, and the same observation applies to silicon. Manganese and phosphorus appear to vary with the conductivity. In all the samples examined the proportion of sulphur was very small, and varied irregularly.

File Steel.—In a paper read by M. Böker ‡ before the German Society of Arts, the author referred to carbon as the main steel-forming

* *Mittheilungen aus dem königlichen technischen Versuchsanstalt zu Berlin*, 1888. No. 2.

† *Ibid.*, 1888. ; No. 1.

‡ Paper read at the Meeting in November 1888.

element. The value of a tool steel varies directly with the percentage of carbon and inversely with the percentage of phosphorus the metal contains. The author illustrates this statement by showing the effect of the carbon in a file on the quantity of work which can be done in a given time by files containing different percentages of carbon; and he adds that in files the percentage of carbon should vary within the limits 0·9 and 1·3, according to the character of the file. The metal used should be good crucible steel, and should contain not more than 0·04 per cent. of phosphorus.

Weak Spots in Ingot Iron Test Pieces. — Professor A. Ledebur* remarks that in testing ingot iron, the test pieces very frequently show a dull lustreless spot at the point of fracture. The metal at such spots has a different composition to that of the body of the test piece, as the following example shows :—

	Sulphur.	Phosphorus.	Silicon.	Manganese.
Weak spot	0·13	0·15	0·03	0·31
Sound portion	0·06	0·04	0·03	0·25

The carbon was not determined.

In another instance the author states that the sulphur at the weak part of the test piece was as much as 0·3 per cent. whilst in the sounder portion it was only 0·04 to 0·05. These parts are, therefore, evidently the result of liquation; as has been already pointed out by Eccles. Still, this liquation is possibly simply the result of the contraction of the metal in the casting, and it is to the formation of such hollows caused in this way that the author considers the formation of these weak places to be due. When a test piece which shows flaws of this nature at the point of fracture is cut lengthwise, and the surface etched, it is at once evident that the cooling of the metal has been an important factor in their formation. The author publishes five illustrations in proof of this statement. The liquation, however, does not take place solely in the direction of the interior of the ingot or test piece, but also towards the sides, and the author has always observed the formation of liquated globules on the surface of such ingots. In the case of an ingot of open-hearth metal, the partial composition of the liquated globule and of the ingot itself were as follows :—

	Sulphur.	Phosphorus.
Globule	0·08	0·10
Ingot metal	0·03	0·06

* *Stahl und Eisen*, vol. ix., pp. 13-15.

Generally the difference is still greater than in the instance just mentioned.

Behaviour of Tempered Steel.—Mr. B. Pensky* notes that steel rods after tempering increase in volume, while the length may increase or decrease according as the ratio surface to volume is either below or above a certain limit. Subsequent to tempering, the rods become shorter at ordinary temperatures. By heating, a further diminution in length was observed. Very hard steel discs behaved similarly with regard to their diameter.

Chrome Steel.—Mr. B. F. Hart and Mr. J. Calisch† discuss the manufacture of chrome steel at Brooklyn, and the tests employed in connection with the material used at St. Louis bridge. They give the following analyses:—

	No. 1 Steel.	No. 1 Steel.	No. 3 Steel.	No. 3 Steel.
Carbon	1·107	1·145	0·725	0·742
Phosphorus	0·035	0·041	0·018	0·016
Chromium	0·759	0·682	0·513	0·528
Silicon	0·129	0·134	0·175	0·161
Sulphur	0·006	0·006	0·005	0·006
Manganese	0·022	0·022	0·010	0·010

	Magnet Steel.		Rock Drill Steel.	
	No. 1.	No. 2.	No. 1.	No. 2.
Carbon	0·957	0·965	0·851	0·848
Phosphorus	0·052	0·044	0·022	0·019
Chromium	0·494	0·597	0·545	0·408
Tungsten	0·618	0·761	—	—
Silicon	0·055	0·061	0·125	0·133
Sulphur	0·004	0·005	0·006	0·005
Manganese	0·017	0·017	0·011	0·009

These samples were produced at the Chrome Steel Works, Brooklyn; No. 1 steel being used for turning, planing, and other tools requiring a steady cut; No. 2 steel is made for all fine edge tools, chipping chisels and machine shop tools.

* *Iron*, vol. xxxiii., p. 78.

† *Ibid.*, xxxiii., p. 32.

Fractures of Steel Ingots and Rails.—Mr. R. W. Hunt* publishes a large number of illustrations showing the fractures of steel rails and of ingots, in defence of section 10 of his proposed Specifications, which reads as follows:—"After the ingots are cast they shall be either constantly kept in an upright position, or else so maintained until the interior steel has had time to solidify." He also replies in detail to the criticisms his suggestions have evoked.

Tests of Rivet Steel.—The following results of a series of mechanical tests of rivet steel, which were made in 1883 by Mr. W. H. Burr at the Rensselaer Polytechnic Institute, Troy, United States, have been recently published in the *Iron Age*†:—

Number of Specimens.	Diameter of Specimens in inches.	Stress in lbs. per square inch at		Elongation in 8 inches Per cent.
		Elastic Limit.	Ultimate Resistance.	
2	0·73	40,100	62,600	26
3	0·74	37,200	62,300	28
4	0·734	37,800	60,500	30
5	0·728	38,500	61,100	28
6	0·73	37,300	61,200	29
7	0·73	37,300	62,100	25
8	0·734	36,900	61,500	31
9	0·725	43,100	70,700	26
10	0·73	42,200	60,200	29
11	0·73	39,600	63,500	30
12	0·73	39,600	60,200	30
13	0·726	39,100	61,300	27
14	0·73	37,300	58,800	30
15	0·725	38,700	60,500	31
16	0·729	39,300	61,400	31
17	0·724	37,840	61,450	29
18	0·724	38,350	61,200	32
19	0·725	38,700	61,500	27
20	0·725	37,300	61,240	30
21	0·726	38,900	62,300	28
22	0·725	38,740	62,000	28
23	0·73	39,000	60,200	30
24	0·73	37,500	60,200	27
25	0·73	39,200	61,200	28
26	0·73	37,300	61,100	26
27	0·725	38,740	62,200	25
28	0·73	39,600	59,200	29
29	0·73	41,050	64,440	28
30	0·73	38,200	60,200	28
31	0·73	37,300	61,200	28
32	0·73	38,400	60,200	30

* *Iron Age*, vol. xliii., p. 196. † Vol. xlii. p. 658.

The specifications required an ultimate tensile strength of at least 60,000 lbs., and a final elongation in 8 inches of not less than 23 per cent. An excess over 60,000 lbs. was allowed, provided the elongation remained at least 23 per cent.

Tests of Steel Eye-Bars.—According to the *Iron Age* * the Edge Moor Iron Company have recently made a number of tests of steel eye-bars manufactured by Messrs. Carnegie, Phipps & Co., of Pittsburgh. The diameter of the eye was in every case 12·5 inches, whilst the diameter of the pin-hole was 4·96 inches. The first two were 15 feet in length, and the second two 18 feet:

	1.	2.	3.	4.
Per cent. excess, Eye A	59·6	56·8	56·1	62·5
Per cent. excess, Eye B	55·0	59·7	56·6	56·2
Size of bar	$5 \times 1\frac{5}{16}$	$5 \times 1\frac{1}{8}$	$5 \times 1\frac{1}{8}$	5×1
	ft. in.	ft. in.	ft. in.	ft.
Length, back to back, of holes	16 11	16 11	29 $11\frac{5}{8}$	32 $6\frac{1}{4}$
Elastic limit, lbs.	36,520	36,700	36,740	39,550
Elongation of hole, A	0·35	0·54	0·75	0·74
Elongation of hole, B	0·40	0·76	0·56	0·57
Elongation on 8 inches, per cent.	41·2	39·2	39·6	37·5
	In 15 feet.		In 28 feet.	
Elongation on total length, per cent.	13·1	15·3	16·4	11·4
Reduction of area, per cent.	51·5	49·0	46·7	43·3
Ultimate strength, lbs. per sq. inch	64,030	64,680	66,140	63,700

The fracture of the first two eye-bars was capped and silky, whilst that of the second two was 45 per cent. silky. In the first the fracture took place 3 feet 11 inches from the back of pin-hole B; in the second, 3 feet 3 inches; in the third, $16\frac{1}{4}$ inches from pin-hole A, and in the fourth; 2 feet $9\frac{3}{16}$ inches from pin-hole B.

Tests for Proving Bayonets and Swords.—Instructions † have been issued to the Ordnance Store Department from the War Office for subjecting sword bayonets and naval swords to specific tests prior to their being passed into store for issue or re-issue to the service. Diagrams are appended to these instructions. The long naval sword

* Vol. xlii. p. 463.

† *Engineer*, vol. xlvii. p. 212.

is bent at the point to nearly a right angle during the test, and the sword bayonet to an angle of about 50°. For the naval 27-inch sword both flats are bent over a curved block, so that every portion of the blade partakes of the bend, and the sword is also struck moderately on back and edge on an oaken block. The naval 25½-inch sword is sprung over a bridge piece at the centre, 3⅛ inches high on both flats, and is also submitted to the striking test. For the 1887 pattern sword-bayonet both flats are bent over a curved block, and a moderate blow is struck on both flats on an oaken block.

Iron for Building Purposes.—Messrs. Müller and Lühman * have made comparative experiments on cast and wrought iron when heated with and without protection from flame. It was found that red-hot pillars of good cast iron did not crack when cold water was poured on them. Thick cast iron pillars, whether hot or cold, stood one and a half times as much pressure as wrought iron pillars of the same section. In case of lighter columns with a diameter less than one-twentieth of the length, there was not much difference between cast and wrought iron. When pressure was first applied, it took more effect on cast than on wrought iron; but as the pressure increased, this was reversed, and the wrought iron buckled more rapidly. In the final tests cast iron broke, while the wrought iron bent. When red hot, both irons carry about half the weight which they are capable of carrying when cold. Cast iron became red-hot slightly more quickly than wrought iron, but no difference was found in the rate of heating of solid and hollow pillars. When protected from direct contact with flame, the pillars will resist for several hours longer. It is concluded that cast and wrought iron can be used with equal safety for building purposes.

Recent Testing Machines.—In a paper read before the Sheffield Society of Engineers, Mr. J. H. Wicksteed gave a description of the 450-ton Emery testing machine at the Watertown Arsenal. This machine is capable of exerting a stress of 800,000 lbs., and of testing specimens up to 30 feet in length. Before acceptance by the Board, a link of hard iron five inches in diameter was placed in the machine, and slowly strained in tension till it broke at 722,000 lbs. Without any adjustment, a horse hair was then fixed in the machine, and broken at an indicated stress of 1 lb. The Emery machine is a compound lever machine, with a hydraulic press acting on one end of the speci-

* *Industries*, vol. v. p. 437.

men, and a lever weighing apparatus, a peculiarity being that a kind of hydraulic lever is introduced between the specimen and the weighing apparatus. Each ton of stress on the specimen is balanced by $1\frac{3}{4}$ oz. on the weighing apparatus, giving a leverage of about 19,000 to 1, 14 lbs. balancing 133 tons (of 2000 lbs.). In the Wicksteed machine a rigid cast iron standard is bolted to the foundations, and at the top there is a horn projecting back to carry the principal knife-edge or fulcrum of the lever. The main lever rests on the top of the standard by means of a knife-edge, and a second knife-edge behind this supports the upper shackle for gripping the specimen. A jockey-weight running on the main lever forms the weighing apparatus, and a hydraulic ram, worked by a quiet screw compressor, takes up the deformation of the specimen. The knife edges are three inches apart in the 60-ton machine, and to prevent fissure they are gripped by rigid castings bolted between the side plates of the lever. The jockey-weight weighs exactly one ton, and can be moved along the lever by a screw driven at will either by hand or power. Each three inches of movement of the jockey-weight adds one ton to the load on the specimen, whilst the vernier attached to the jockey-weight reads on the scale affixed to the great lever to 1-100th of a ton, or 22·4 lbs. For holding the specimen, Mr. Wicksteed has designed a very ingenious grip, consisting of double conical surfaces acting upon serrated wedges, arranged in such a manner as to render unfair straining of the specimen impossible, and giving accurate results; a very important point in connection with the gripping shackles being the facility with which specimens are placed and withdrawn after fracture. In the Wicksteed autographic apparatus, for recording the behaviour of the specimen by an indicator diagram, the motion of the pencil which indicates the load is derived from the fluid pressure in the hydraulic press, and not from the weighing apparatus; a wire attached by clips to the specimen serving to rotate a recording drum by an amount proportional to the elongation. The pencil having an axial motion proportional to the load, and the drum a motion of rotation proportional to the extension, a stress strain diagram is described. In Unwin's device for obtaining autographic stress strain diagrams, motion is given to the paper cylinder on which the diagram is recorded by a worm and wheel, which derive their movement from the large screw giving motion to the jockey-weight on the greater lever of the machine, the rotation of this screw being exactly proportional to the movement of the weight, and to the stress on the specimen.

A single lever 100-ton testing machine has been erected at Owens College, Manchester. A special feature is that pumping engines are dispensed with, and the required water pressure is obtained by an intensifier. Illustrations are given in *Industries*.*

M. Rudeloff† discusses the various types of testing machines that have been proposed. He divides them into: (1) screw power lever machines; (2) hydraulic lever machines; and (3) machines with hydrostatic measuring attachments. The author gives a number of examples of machines belonging to each of these classes, and illustrates his references by diagrammatic sketches showing the general scheme of the construction adopted. Detailed drawings of portions of some of the machines are also given.

Regulations for the Delivery of Iron and Steel.—The German Iron and Steel Institute has issued, in pamphlet form, a series of regulations relating to the fulfilment of trade orders for iron and steel materials. These regulations are divided into a number of classes each of which is again divided into a number of subdivisions. The regulations refer to: (1) railway material; (2) iron for construction purposes; (3) sheets; (4) merchant iron; (5) wire; and (6) foundry iron. In a series of general regulations, referring to the whole of these classes, the various mechanical tests are defined, as also are both the size and shape of the test pieces to be employed. No particular form of testing machine is mentioned, but it is required that the action of the machine must be regular, and that the test pieces shall be submitted to stresses which increase gradually. Further, the test piece must be placed in the testing machine in such a manner that the longitudinal axis of the test piece shall correspond accurately with the direction in which the jaws of the testing machine are pulled apart. The machine, too, must be so constructed that its accuracy may be easily and readily determined.

All cold tests must take place at temperatures which are not less than 10° C.

The Nomenclature of Iron and Steel.—The German Minister for Public Works has issued an order that in future certain definite names are to be given to the varieties of iron and steel used by the Railway Department. These names are based on the mode of manufacture of

* Vol. vi. p. 344.

† *Stahl und Eisen*, vol. viii. pp. 809–821.

the metal. They may be translated as follows:—Pig iron, cast iron, weld iron, weld steel, ingot iron, and ingot steel. The term "cast iron" signifies pig iron that has been cast into shapes, either direct or after re-melting. The term malleable or wrought iron is no longer to be employed.

A further secondary nomenclature is based on the uses to which the metal is to be put.

CHEMICAL PROPERTIES.

The Nitrogen contained in Ingot Iron.—H. Tholander* discusses the question, "Why is the ingot iron produced in the open hearth of a better quality than that produced by the Bessemer process?" It may, perhaps, be suggested that the Bessemer metal is far less homogeneous in its character than is the open hearth metal, but the great difference that may exist in the percentages of nitrogen dissolved in the respective metals is generally overlooked. In the Bessemer process nitrogen is blown through the molten iron, whilst in the open-hearth process the metal is protected from atmospheric action by a layer of slag. Chemical compounds of iron with nitrogen have long been known, but the affinity between the two elements does not appear to be very great. The author has made a series of comparative determinations of the nitrogen contained in Bessemer and in open-hearth metal, the method he employed being that of Boussingault, which depends on the nitrogen of iron nitride and of iron cyanide being converted into ammonium sulphate, when the iron in which the nitride is contained is dissolved in sulphuric acid. The ammonia is then driven out by an equivalent quantity of soda, collected and determined in the ordinary manner. The author, after describing the precautions he took to obtain sulphuric acid, soda, and water free from nitrogen, gives the results of the analyses which he made. These results are as follows:—

	Percentage Composition.		
	Carbon.	Silicon.	Nitrogen.
Avesta Bessemer iron . .	0·05	0·006	0·015 0·015
„ „ „ . . .	0·05	0.009	0·015 0·019
„ „ „ . .	0·10	0·012	0·020 0·015
„ „ „ . .	0·10	0·014	0·016 0·022
„ „ „ . .	0·10	...	0·012
„ „ „ . .	0·15	...	0·020

* *Jernkontorets Annaler*, vol. xliii. No. 7.

The metal of another charge which had been overblown for three minutes, contained before the addition of ferro-manganese, 0·05 carbon, 0·022 silicon, and 0·032 per cent. of nitrogen, and after the addition of sufficient ferro-manganese to raise the carbon to 0·10 per cent., the percentage of nitrogen remained unaltered.

A number of samples of open-hearth metal plate gave as a rule much lower results, as the following table shows :—

	Percentage Composition.		
	Carbon.	Silicon.	Nitrogen.
Hammarby metal, ore process .	0·10	0·011	0·006
" " " .	0·10	0·008	0·005
Finspong metal, scrap process .	0·10	0·011	0·008
" " " .	0·10	0·012	0·008
" " " .	0·10	0·014	0·005
" " " .	0·10	0·014	0·006
Avesta metal, scrap process .	0·10	0·010	0·012
" " " .	0·10	0·010	0·012
" " " .	0·10	0·012	0·013
" " " .	0·10	0·019	0·008
" " " .	0·15	0·021	0·012

Samples taken at regular periods throughout the whole duration of an open-hearth charge, showed the percentage of nitrogen to vary between 0·010 and 0·017, the percentage gradually diminishing, and being at its lowest in the finished metal.

The pig iron used at Avesta in the open-hearth process was found to contain about 0·010 per cent. of nitrogen, the percentage found by analysis having been as follows :—

	Silicon.	Nitrogen.
	Per cent.	Per cent.
Large-grained grey pig iron . . .	0·41	0·010
Fine-grained grey pig iron . . .	0·10	0·012
Mottled pig iron	1·41	0·011
White pig iron	1·10	0·005

Samples of crucible steel were found to contain from 0·006 to 0·008 per cent. of nitrogen.

Two 6-inch bars of soft Bessemer iron, each bar being 1 inch wide

and ½ inch thick, were heated to a welding heat and then plunged into a bath of molten potassium cyanide. The bars having been brought to the temperature of the cyanide bath were then removed and the one allowed to cool slowly in air whilst the other was plunged into water. Both pieces were found to have become very hard, but the one which had been plunged into water was harder than the other. Samples were with difficulty removed from the surface layers of each specimen, and on analysis the unhardened metal was found to contain 0·294 per cent. of nitrogen, and the metal which had been suddenly cooled 0·314 per cent. The next layer, lying immediately below the first or surface layer which had been removed, was found to contain 0·161 per cent. of nitrogen. The percentage of carbon in the slowly cooled sample had increased from 0·10 to 0·15.

Other samples of metal which had been similarly treated were also found to have absorbed large quantities of nitrogen, the hardness increasing with the percentage of nitrogen.

The author is of opinion that the bad effects of an over-blow in the Bessemer converter, on the quality of the metal produced, is not due to oxidation but to the absorption of nitrogen. Finally, the author observes that if an extra soft open-hearth metal is required to be produced, the following conditions must be observed:—(1) pig iron as free as possible from nitrogen must be used—preferably charcoal iron made at a low temperature; (2) rich ore to be used in the decarburisation; (3) water gas to be used; and (4) the lining of the open-hearth to be of a neutral character.

Occlusion of Gases in Iron.—According to Finkener,* a cavity of 12·34 cubic centimetres in a Mannesmann tube contained 9·11 cubic centimetres of gas at a pressure of 760 millimetres and 0° C. The gas consisted of 99·0 per cent. of hydrogen and 1·0 per cent. of nitrogen. The analysis of turnings from the tube yielded the following results:—

Carbon.	Silicon.	Phosphorus.	Sulphur.	Manganese.	Sulphur.
0·46	0·25	0·022	0·01	0·23	trace

The Influence of Oxygen on Iron.—Dr. F. Muck† discusses the influence of the air dissolved in the water used in boilers on the boiler plate of which they are constructed. He refers to a curious formation of rust in the interior of a boiler. The rusting action had been greatest

* *Mittheilungen aus dem kgl. technischen Versuchsanstalt zu Berlin*, 1889, p. 41.
† *Stahl und Eisen*, vol. viii. pp. 837-841.

in the immediate vicinity of the feed-pipe. The boiler plate was pitted considerably, and above each of such pits was a fungus-like growth of rust, the composition of which, dried at 100° C., was as follows:

Fe_2O_3.	FeO.	CaO.	MgO.	SiO_2.	SO_3.	CO_2.	C.	H_2O.	Organic Matter
66·84	23·24	2·60	0·39	1·18	0·28	2·32	0·22	2·75	0·18

The organic matter referred to was soluble in ether, and probably originates in the lubricating materials used. The rust, therefore, consisted mainly of magnetic oxide.

The feed water used was found to have the following composition in grammes per litre :—

NaCl.	Na_2SO_4.	$CaSO_4$.	$CaCO_3$.	$MgCO_3$.
0·0306	0·0351	0·0036	0·0595	0·0145

The relatively large quantity of sodium sulphate was due to the addition of soda to the water used, to prevent the formation of a compact deposit in the boiler. The quantity of fat contained in the boiler water was small, and not sufficient to account for the oxidation observed. The only accountable agent that could have produced it is the atmospheric air dissolved in the water. The curious shape of the fungus-like growths was probably due to the formation of hydrogen. Other similar cases are also mentioned by the author.

Carbon in Iron.—A. Ledebur* discusses the names given to the various modifications of carbon occurring in iron. Originally only two modifications were recognised, (1) graphite, and (2) "combined" carbon. Now, however, it is known that there are many varieties of this so-called "combined" carbon, and that these differ considerably in their properties. In certain cases, when the iron or steel is dissolved in cold acids, the whole of the carbon escapes in the form of a hydrocarbon; in others, it remains with considerable quantities of iron as a black residue, which is only decomposed by boiling acids. The first of these forms of carbon was originally termed "hardening" carbon, as it mainly occurs in hardened steel; the second modification was termed "cement" carbon, since it is found in steel which has been annealed. Both these carbon modifications are, however, not found in steel only, but also in other forms of iron, especially in grey and white pig iron. The form of carbon residue, too, which is classified under the name of "graphite," does not always exhibit exactly the same properties, and

* *Stahl und Eisen*, vol. viii. pp. 742-747.

from a consideration of the various known facts the author has been led to adopt the following classification: (1) Hardening carbon; (2) ordinary carbide carbon; (3) graphitic temper carbon; and (4) graphite.

(1.) *Hardening Carbon* occurs in almost all varieties of iron. It is sharply defined from the other forms of carbon in that it escapes as a strong-smelling hydrocarbon when the iron in which it exists is dissolved in dilute sulphuric or hydrochloric acid. When the iron is dissolved in nitric acid of 1·2 specific gravity, this carbon is stated by Osmond and Werth to be in the first place left undissolved in the form of a deep black residue, which dissolves rapidly and without any apparent ebullition of gas when the solution is shaken. When the solution is raised to 100° C., it gradually escapes as a gas. The solution, which was originally of a deep colour from the dissolved carbide, becoming gradually lighter and lighter as the hydrocarbon boils away. The only method for determining it quantitatively consists in determining first the total carbon, and then the various modifications other than the hardening carbon, and then subtracting the combined weights of these various forms from the total percentage of carbon found.

The hardening carbon is evenly disseminated through, and alloyed with, the cooled iron, and endows it with the high degree of hardness possessed by steel.

(2.) *Ordinary Carbide Carbon* is nearly always present in iron and steel. When the metal in which it occurs is dissolved in strongly diluted sulphuric or hydrochloric acid it remains as a grey residue together with from thirteen to sixteen times its weight of iron. If the metal is dissolved in nitric acid of 1·2 specific gravity, the carbon remains in the form of a voluminous brown residue, which dissolves gradually when the acid is heated, without any apparent evolution of gas. The solution is coloured brown, and this coloration is only slightly lessened even after continuous boiling. It differs, therefore, in this respect from the first type, or hardening carbon. It may be quantitatively determined by dissolving the metal in very dilute cold sulphuric acid, out of contact with the air; collecting the residue on an asbestos filter and burning in the ordinary way. From the total carbon thus found, the weights of the graphite and of the graphitic temper carbon having been deducted, the weight of the carbide carbon is obtained.

When steel, which is being slowly cooled from a high temperature, reaches that lying between 600° and 700° C., the iron carbide liquates out, as it were, from the main mass of metal containing the

carbon in the hardening form, the only form in which the carbon was present when the metal was at a greater heat. The more slowly the metal is cooled the higher does the ratio borne by the carbide carbon to the hardening carbon become. This ratio is in no wise affected by any mechanical treatment to which the metal may have been subjected, and this completely overthrows the theory of Caron, that mechanical treatment of the metal in the cold has the same effect on the carbon as is produced by suddenly cooling it when at a high temperature.

(3.) *Graphitic Temper Carbon.* Carbide carbon is rapidly converted into this other modification when the metal is kept at a red heat for a lengthened period. The "temper" carbon differs from the "carbide" form in that it is neither dissolved nor volatilised by the action of boiling acids, but remains as a residue of almost pure carbon when the iron is boiled for some hours with strong hydrochloric acid; the residue washed with water, and then, consecutively, with caustic potash, water, alcohol, and ether. In this respect it behaves in a manner identical with that of graphite, and at present there exists no method for determining separately these two modifications. When observed, it has therefore, hitherto, always been determined as "graphite." An important distinction between graphitic temper carbon and graphite lies in the fact that the former may be almost completely eliminated from iron by the prolonged heating of the metal under oxidising conditions, whilst the graphite is scarcely affected by this method. Forquignon has even shown that a simple heating of the iron in a current of hydrogen suffices for the elimination of the temper carbon, which escapes in the form of a hydrocarbon. The temper carbon, too, differs from graphite in its appearance, being completely amorphous and deep black, but without lustre. This form of carbon exists in considerable quantities in white pig iron poor in manganese which has been heated to redness for several days. The metal is then found when fractured to have become spotted, some places having become grey coloured through the formation of temper carbon. The metal in these places becomes slightly malleable, and in connection with this the author mentions the case of a sample of iron, containing 2·45 per cent. of carbon, which was submitted to him for examination. This metal contained 0·59 per cent. of the temper carbon, and at a brown-red could be hammered and hardened. After having been many times annealed the percentage of temper carbon was found to have increased to 1·24. Malleable cast iron almost always contains this form of carbon. Unhardened steel, too, frequently contains small quantities

of temper carbon. Cement steel, however, which would appear theoretically to be the metal most likely to contain large quantities of this form of carbon, usually contains but relatively small quantities.

(4.) *Graphite.* Like the "carbide" and "graphitic temper" forms of carbon, graphite is the product of a decomposition, of a liquation of the iron-carbide present in molten iron; whilst the two other modifications are produced after the metal has solidified, the graphite is only formed during the passage of the metal from the fluid to the solid state, and for its separation not only is a certain percentage of carbon in the iron necessary but silicon must be also present.

The author gives the following results of some carbon determinations, showing the relative quantities of the various modifications of carbon which were present in the metal examined:—

	1a.	1b.	2.	3.	4.	5.
Hardening carbon	0·85	0·27	0·21	0·05	0·42	0·19
Carbide carbon	1·23	0·00	1·51	0·67	1·07	0·97
Graphitic temper carbon and graphite	1·26	3·04	2·21	0·91	0·00	0·04
Totals . . .	3·34	3·31	2·93	1·63*	1·49	1·20

1a. Hard casting; 1b. same annealed for 108 hours; 2. an annealed casting; 3. the same casting after annealing in hæmatite—this sample also contained 0·88 per cent. silicon and 0·12 per cent. manganese; 4. Swedish cement steel; 5. cement steel from Remscheid.

Another example of white iron poor in manganese, which had been heated in charcoal, was found to contain after such treatment 1·44 per cent. of graphitic temper carbon and 0·42 per cent. of hardening and carbide carbon. It was hammered at a red heat into a thin rod and the percentage of temper carbon re-determined. It had diminished to 1·28 probably through oxidation. In another experiment a sample of ingot iron produced by the basic open-hearth process was found to contain 0·13 per cent. of carbon, the carbon being wholly in the carbide form.

In connection with the determinations of carbide carbon, the author also determined the weight of the iron with which this carbon was associated in the various residues examined. The iron varied in weight from about 14 to rather more than 16 times the weight of the carbon.

* 1·69 in original.

Action of Hydrochloric Acid on Cast Iron.—From the results of a series of experiments, Prost * concludes that the amount of the residue varies in proportion to the concentration of the acid, from 41·33 to 4·19 per cent. The composition of the residue is similarly affected, the proportion of carbon, hydrogen, and phosphorus being increased with increased concentration, whilst the proportion of iron is highest with the weakest acid. Besides being combined with carbon, the hydrogen is perhaps present in combination with iron, or in the form of volatile hydrocarbons. Part of the sulphur is present in cast iron as an insoluble organic sulphur compound.

Rusting of Ironwork in Tunnels.—On account of the sulphurous anhydride in the gases evolved from locomotives, the ironwork of tunnels is attacked by the sulphuric acid formed. In samples of rust as much as 0·4 to 3·1 per cent. of sulphuric acid has been found. Frederking † suggests a number of methods of obviating this inconvenience. Amongst other methods, he proposes a coating of tar for the ironwork, the employment of coals as free as possible from sulphur for firing the locomotives, limiting the amount of steam and smoke evolved in the tunnels, and calciferous bedding material.

The Chemical Composition of Steel Rails.—In the discussion which has ensued in connection with the specifications relating to the testing, &c., of steel rails as suggested by Mr. W. R. Hunt,‡ Mr. E. P. Hannaford, § the chief engineer of the Canadian Grand Trunk Railway, states that for a 65 lb. steel rail he considers the following to be the best composition :—

Carbon.	Silicon.	Phosphorus.	Manganese.
0·40	0·06	0·07	1·10 to 1·20

If the weight of the rail is increased to 75 lbs. or 80 lbs., the percentage of carbon may be increased to 0·50 or 0·55.

Mr. Robert Sayre || of the Lehigh Valley Railway, believes that the percentage of carbon should be about 0·50 or 0·55, to which he has increased it from 0·40 as formerly employed. He agrees with Mr. Hannaford in believing that as the weight of the rail is increased, the percentage of carbon may also be raised, and with good results.

* *Bulletin de l'académie royale de Belgique*, 1888, pp. 216–232.
† *Centralblatt für Bauverwaltung*, 1889. No. 16.
‡ This Journal. § *Iron Age*, vol. xliii. p. 157. || Ibid, p 156.

CHEMICAL ANALYSIS.

CONTENTS.

	PAGE		PAGE
I. Analysis of Iron and Steel .	391	III. Fuel Analysis	401
II. Analysis of Iron Ores and Slag .	400	IV. Gas Analysis	401

I.—*ANALYSIS OF IRON AND STEEL.*

International Standards for the Analysis of Iron and Steel.—In connection with the British Association for the Advancement of Science, a committee was appointed to consider the best method of establishing international standards for the analysis of iron and steel. It is proposed that the committee shall co-operate with other similar committees in the more important iron-producing countries, in order to provide standard specimens of iron and steel, the chemical composition of which shall have been carefully determined. The specimens adopted as standards shall be entrusted to some recognised official authority, such as the Standards Department of the Board of Trade, and shall be used either for reference in the determination of the accuracy of any proposed method of analysis, or for controlling the results of analyses in any cases of importance which may from time to time arise.

The secretary notes that the preliminary arrangements made by the committee are as follow:—

1. Professor J. W. Langley of the University of Michigan, U.S.A., to be requested to superintend the production of the samples; that they be prepared and preserved in accordance with the directions to be furnished by the committee, and that an equal portion of each sample be forwarded to the several secretaries of the respective committees in the United Kingdom, the United States, France, Germany, and Sweden.

2. The specimens which are eventually to be adopted as standards,

to be supplied to not more than seven representative chemists of repute in each of the countries above mentioned, who shall be requested to analyse the specimens by any method or methods they may prefer.

3. In the event of the analyses giving results which, in the opinion of the committee, may be regarded as sufficiently concordant, the means of the analytical results of each of the several constituents to be adopted as representing the composition of the standards. The report of the analytical results not to be issued until the various analysts to whom the samples have been submitted shall have had an opportunity of examining it. The standards shall hereafter be distinguished only by letters or numbers.

4. The attention of the committee to be for the present confined to four samples of steel, selected as containing as nearly as possible 1·3, 0·8, 0·4, and 0·15 per cent. of total carbon respectively. In addition to the determination of the amount of carbon present in each condition, the phosphorus, sulphur, silicon, manganese, and chromium are also to be determined.

5. 150 kilogrammes of the samples selected for examination as standards to be prepared in all. This would give, after allowing sufficient for the required analyses, quite 5 kilogrammes of each standard for each of the five countries interested. Allowing, say 10 grammes, for each applicant who may desire to use the standards, this would permit of 500 appeals to each of the four standards in each country, or at least 10,000 appeals in all.

6. The samples to be analysed in the United Kingdom by W. Jenkins, Dowlais; Edward Riley, London; J. E. Stead, Middlesbrough; the Royal School of Mines; G. S. Packer, of the Steel Company of Scotland; and two others.

7. The metal of which the samples are to be produced to be cast in small ingots, special care being taken to prevent any irregularity of composition. After the removal of the outer skin the metal to be cut by a blunt tool in the form of thin shavings, then crushed, sieved, and intimately mixed.

8. The samples thus prepared to be preserved in separate small quantities, say of 30 grammes each, which shall be hermetically sealed in glass tubes so as to prevent oxidation.

In connection with this subject, in the criticism which accompanies the translation of the proposals which appears in *Stahl und Esien*,* it is pointed out that the first and main difficulty will lie in

* Vol. ix. p. 207.

the preparation of such a large quantity—150 kilogrammes—of steel of exactly the same chemical composition. It is further observed that some slight variations in the composition of the metal may render one or other of the chemical methods of analysis employed unsuitable for the material under examination; thus, for instance, the bromine method for the determination of sulphur is inapplicable when the metal to be examined is either ferro-manganese or spiegeleisen, or even pig iron containing considerable quantities of copper. This method again cannot be used for ferro-silicon, as some silicon chloride passes into the bromine solution. For this reason only hydrochloric acid can be used to dissolve ferro-silicon, when the percentage of silicon is to be determined. Any standard method of analysis is therefore only adapted for use in connection with samples of similar composition.

Determination of Carbon in Iron.—In the process in which the iron is dissolved by a mixture of cupric and ammonium chlorides, and the residue oxidised by sulphuric and chromic acids, it is necessary, L. L. de Koninck* finds, to wash the chlorides out of the residue very completely, otherwise chlorine will be evolved with the carbonic anhydride. The addition of an excess of silver sulphate to the mixture in the oxidation flask obviates this difficulty, no chlorine being evolved.

Mr. T. W. Hogg† proposes the use of ferric chloride in conjunction with cupric chloride for separating carbon from irons and steels. The ferric chloride reacts on the cuprous chloride, which is often precipitated when cupric chloride is used alone, and forms cupric and ferrous chlorides. The method adopted is to use sufficient cupric chloride solution of 1·35 specific gravity to cover the sample to the depth of half an inch. A considerable excess of ferric chloride solution of 1·30 specific gravity is added, and the liquid is then stirred for five minutes. Heat gently to boiling for about twenty minutes, add a few drops of hydrochloric acid, and filter off the carbonaceous residue for further treatment. The solution should not be allowed to stand, or gelatinous silica is likely to be precipitated.

Mr. H. N. Warren‡ describes the various forms of graphite remaining from the solution of metals in dilute acids. Nickel and cobalt give a graphite closely resembling lamp-black. Ferro-manganese leaves scales which are thinner than those obtained from cast iron, and they have a

* *Zeitschrift für analytische Chemie*, vol. xxvii. pp. 463–464.
† *Chemical News*, vol. lviii. pp. 199.
‡ *Ibid.*, vol. lix. p. 29.

distinct brownish tint. With manganese the scales are perfectly brown, and often large and translucent. Chrome iron gives brighter and harder scales than iron, and chromium itself gives scales of a semi-metallic lustre closely resembling silicon.

According as the metal is more difficult of fusion, so is the graphite of a more stable form. The various forms can be changed by fusion with various metals.

Influence of Sulphur on Eggertz's Carbon Colour Tests.—Mr. T. W. Hogg * finds that the presence of sulphur in steels interferes with Eggertz's carbon colour test on account of the turbidity produced. Pure Swedish steels containing only a trace give a perfectly clear solution, but steels containing say 0·05 per cent. of sulphur give solutions differing decidedly in clearness, and when the sulphur rises to 0·5 per cent. it is impossible to make satisfactory tests. Sulphur in the form of magnesium sulphate has no effect, the only alteration is shown when suspended sulphur is present owing to imperfect oxidisation by the nitric acid used for solution. On adding a small proportion of milky suspended sulphur to a steel solution, it is found to take a decidedly browner hue.

The Determination of Manganese.—As in the case of chromium, A. Carnot † finds that whilst the acid solution of manganic acid is reduced by hydrogen peroxide, the lower oxides in alkaline solution may be further oxidised. If to a manganous oxide solution a few cubic centimetres of hydrogen peroxide are added, then an excess of ammonia, and finally the solution boiled, a dark coloured precipitate is formed, which contains the whole of the manganese. This precipitate is not, however, pure, but contains other bases, which may be separated from the manganese by frequent and rapidly executed solutions and re-precipitations. The manganese oxide is then dissolved, and determined volumetrically by the oxalic acid method. The manganese precipitate produced by the hydrogen peroxide is of constant composition. It is not pure peroxide, but has the formula $5MnO_2 + MnO$.‡

In the method for the determination of manganese in steel adopted by Mr. F. Julian, § one gramme of metal is dissolved in 15 cubic

* *Chemical News*, vol. lviii. p. 175.
† *Comptes rendus*, vol. cvii. p. 997. ‡ Ibid, vol. cvii. p. 1150.
§ *Journal of Analytical Chemistry*, vol. ii. p. 249.

centimetres of nitric acid (specific gravity 1·2), evaporated down to 5 cubic centimetres, 20 cubic centimetres of strong acid are added, and the liquid is precipitated by potassium chlorate. There are then added successively to the mixture 5 cubic centimetres of strong nitric acid, 60 cubic centimetres of hot water, and 10 cubic centimetres of ammonium oxalate (15 grammes per litre). The liquid is agitated until it assumes a light yellow colour, and the excess of oxalic acid is titrated by means of permanganate, the operation being performed at a temperature of 70° C. The manganese dioxide dissolves rapidly under the influence of oxalic acid. The back titration is rapidly effected, and the end of the reaction is easily found after a little experience.

The Determination of Phosphorus.—Dr. M. A. von Reis* observes that the great difficulty which is experienced in obtaining the molybdate precipitate absolutely free from iron is well known. Even after very careful washing a quantity of iron always remains in the precipitate, and in the re-precipitation by the magnesia method, the ignited precipitate is more or less red if the percentage of phosphorus in the iron examined is below 0·1; if, however, it is above this percentage, the ignited precipitate will appear of a pure white colour, even though iron should be present. The quantity of iron present in such precipitates is not, however, of any real importance. Still the appearance of a red tinge throws doubt on the accuracy of the determination, and the author has therefore experimented, in connection with M. Esser, with a view to the adoption of some means for preventing the passage of the iron into the precipitate. The method finally adopted consists in precipitating the phosphorus by molybdate solution in the customary manner. The molybdate precipitate is very carefully washed, and is then dissolved in about 15 cubic centimetres of a citrate solution obtained by adding 100 cubic centimetres of ammonia of 0·91 specific gravity to a solution of citric acid and then diluting to a litre. Stronger citrate solution should not be used, as in that case, if the percentage of phosphorus is low, the magnesia precipitate would only form with great slowness, or even not at all. The phosphoric acid in the citrate solution is precipitated with magnesia mixture in the ordinary manner, and it is found that the precipitate so obtained is, as a rule, completely free from iron.

In the case of the determination of phosphorus in pig iron or in slag by this method, a somewhat stronger citrate solution may be

* *Stahl und Eisen*, vol. viii. p. 827.

employed—20 grammes citric acid, 200 cubic centimetres of ammonia of 0·91 specific gravity, and 500 cubic centimetres of water. Another modification of the citrate method is also described by the author, who points out that not only is the citrate method more rapid than the old method, but far less nitric acid and ammonia are used. He estimates the cost of washing 50 molybdate precipitates by the old method at 3s. 7½d., and by the citrate method at only 2½d., a difference in favour of the new method of 3s. 5d., or about ¾d. on every analysis.

The Influence of Arsenic on the Determination of Phosphorus.—Dr. M. A. von Reis * states that in the case of a certain variety of pig iron, 0·05 to 0·1 per cent. of arsenic was found to be present, and nearly the whole of this passed into the ingot metal made from this pig iron. It was found that by the rapid methods of determination that are customary in the case of phosphorus but very little arsenic passes into the solution, as for the complete precipitation of the arsenic from 24 to 48 hours are required, as well by the molybdate as by the magnesia methods. The precipitate by the citrate method proposed by the author is sensibly freer from arsenic and other impurities than is the precipitate produced by the ordinary methods.

The Determination of Sulphur.—It has been shown by Meinecke that the determination of sulphur in pig iron by dissolving the metal in hydrochloric acid, and converting the sulphuretted hydrogen produced into sulphuric acid, is inaccurate, a portion, and sometimes the whole of the sulphur remaining in the undissolved residue. He proposed a method of analysis to avoid this difficulty. Dr. M. A. von Reis † has submitted this method to a comparative examination as compared with the sulphuretted hydrogen, Tamm, and Platz methods. Against each of these methods, however, some objection presented itself, and the author finally came to the conclusion that it is best to employ a method similar to that proposed by Eschka for the determination of sulphur in coke. The method he adopts is as follows:—5 grammes of the iron are intimately mixed with an equal weight of magnesia mixture (2 parts magnesia and 1 part soda) in a large-sized platinum dish. The mixture is then placed in a muffle, and heated for ten minutes to a bright red-heat. A porous cake is produced in this manner. This cake is broken down in an agate mortar, and then

* *Stahl und Eisen*, vol. viii. p. 828.
† *Ibid.*, vol. viii. pp. 829-831.

heated again to redness for 20 minutes, being occasionally stirred. It is allowed to cool, and after being transferred to a beaker 100 cubic centimetres of hot water is added. The solution is boiled rapidly for about 10 minutes, and is then filtered. To avoid the difficulty experienced in washing the finely divided iron oxide remaining on the filter, instead of weighing out 5 grammes of the iron take 5·93 grammes, 7 centigrammes being an equivalent for the residue remaining after ignition, which residue occupies a space of about 3½ cubic centimetres. The metal having been treated with the magnesia mixture in the manner described above, water having been added and the solution boiled, the solution is transferred to a measuring flask, the undissolved residue washed into it, the whole cooled and then diluted to 300 cubic centimeters. Of this solution, 250 cubic centimetres, the equivalent of 5 grammes of iron, is filtered through a folded filter. To the filtrate 10 cubic centimetres of hydrochloric acid is added, barium chloride is introduced, and the solution is boiled down to about one-half its previous volume. It is allowed to stand in the hot for 3 or 4 hours, and is then filtered in the ordinary manner. The whole analysis is completed in about 6 hours. The results of a series of analyses are appended to show the accuracy of the method.

Determination of Silicon in Ferro-silicon.—Pig irons containing about 7 per cent. of silicon are insoluble in acids, with the exception of sulphuric acid of specific gravity 1·25, in which they dissolve very slowly on heating. According to Mr. H. J. Williams,* the solution of these alloys may be effected by fusing one gramme with sodium carbonate for fifteen or twenty minutes over the blast-lamp. The fused mass is then treated with water and excess of hydrochloric acid, evaporated to dryness, and the silica filtered off and washed in the usual way. Obtained in this way, it is perfectly white and pure.

The following silicon determinations are some results actually obtained :—

Sample.	I.	II.	III.
No. 1.	10·92	11·01	10·98
No. 2.	10·73	10·75	10·73
No. 3.	7·42	7·48	7·46

* *Transactions of the American Institute of Mining Engineers*, vol. xvii.

Volumetric determination of Chromium.—The gravimetric method of determining chromium in iron and steel is a difficult and tedious process, as before the chromium is precipitated, the silica, ferric oxide, and alumina must be removed. In the method proposed by E. Wahlberg,* these difficulties are obviated, and accurate results obtained. A solution of potassium permanganate is used for titration, and the chromium is converted into chromic acid, which is determined in sulphuric acid solution, by reduction by means of an excess of ferrous sulphate solution containing a known percentage of iron, the excess being determined with a titrated solution of potassium permanganate. The reaction is indicated by the equation:—

$$6\,FeSO_4 + 2\,CrO_3 + 6\,H_2SO_4 = 3\,(Fe_2\,3\,SO_4) + Cr_2\,3\,SO_4 + 6\,H_2O$$

Half a gramme of chrome steel filings is dissolved in 10 to 15 cubic centimetres of boiling nitric acid of a specific gravity of 1·20. The acid is evaporated, and the residue dried. The mass is pulverised in an agate mortar. Larger particles remaining in the beaker are dissolved with a few drops of hydrochloric acid, and transferred to the platinum crucible that is subsequently used, and evaporated to dryness. The fine mass in the mortar is mixed with about 4 grammes of an alkaline oxidising mixture, consisting of 2 parts of magnesium oxide, 1 part of potassium chlorate, and 1 part of anhydrous sodium carbonate. The contents of the platinum crucible are heated to redness, whereby the potassium chlorate decomposes until nothing but potassium chloride remains. This decomposition is necessary, and must be complete, because the presence of chlorate interferes with the titration. For this reason the heating lasts for two hours. With the aid of a wash-bottle, the residue can be dissolved out of the crucible. In this product, all the chromium is present in the form of alkaline chromate, which is extracted with 50 to 100 cubic centimetres of distilled water in a water bath.

The manganese present in the sample is converted into alkali manganate, which imparts a blue colour to the solution. As manganic acid interferes with the titration, it must be removed or decomposed by adding a few drops of alcohol, which reduce it without acting on the chromic acid, provided that the solution is alkaline. After the complete removal of the excess of alcohol, by heating in the water-bath, the solution is acidified by additions from time to time of dilute sulphuric acid. The undissolved magnesia and ferric oxide are filtered

* *Jernkontorets Annaler*, vol. xliii. p. 67.

off, or sulphuric acid is added and heated to dissolve the magnesia and oxide, and to dispense with filtering. The solution is then ready for titration.

In 1000 cubic centimetres of water and 200 cubic centimetres of concentrated sulphuric acid, 10 grammes of ferrous sulphate are dissolved. Of this 25 cubic centimetres are measured off, the quantity being sufficient for a half-gramme sample with 3 per cent. of chromium, and introduced into the solution under examination. For the determination of the iron in the ferrous sulphate solution, 25 cubic centimetres more are taken, and titrated with a standard solution of potassium permanganate. After the excess of ferric oxide in the solution under examination has been titrated with the same standard solution, and the amount of iron found subtracted from that in the 25 cubic centimetres of ferrous sulphate solution, the result gives the amount of iron that, in the form of ferrous sulphate, is decomposed by the chromic acid of the solution. From the equation it is seen that for the reduction of 2 equivalents of chromic acid 6 equivalents of iron in the form of ferrous sulphate are necessary; or, in other words, 1 gramme of iron corresponds to 0·3116 gramme of chromium. The percentage of chromium in the sample may therefore be easily calculated.

As pig iron rich in chromium is not dissolved by nitric acid, it must be finely pulverised and melted with an oxidising mixture. Iron, with 24 per cent. of chromium, can neither be dissolved in nitric acid nor pulverised in a mortar. It must be melted in a plumbago crucible with some other iron with a known low percentage of chromium; or, better, with iron free from chromium, in such proportions that the resulting metal contains about 12 per cent. of chromium. By this method a chromium determination may usually be made in a day.

The method suggested by A. Carnot* for the determination of chromium is based upon the fact that whilst hydrogen peroxide rapidly and completely reduces chromic acid in cold and acid solutions, it, on the other hand, oxidises chromium oxide present in hot alkaline or ammoniacal solutions. To the acid solution of chromium oxide an excess of ammonia is added together with an amount of hydrogen peroxide sufficient for the oxidation of the chromium oxide. The solution is boiled to destroy the excess of the hydrogen peroxide, and the chromic acid formed may then be determined volumetrically in an acid solution by hydrogen peroxide.

* *Comptes Rendus*, vol. cvii., p. 997.

II.—*ANALYSIS OF IRON ORES AND SLAG.*

The Electrolytic Method as Applied to Iron.—Mr. E. F. Smith* adds to the iron an excess of sodium citrate (0·015 gramme of iron to 10 cubic centimetres of sodium citrate solution, made by dissolving 28 grammes of the air-dried salt in 250 cubic centimetres of water) and a few drops of citric acid solution. The solution is electrolysed in a platinum dish by the use of a current liberating 6 to 15 cubic centimetres of oxyhydrogen gas per minute. The iron is deposited in four to eight hours. It is washed with water, alcohol, and ether, then dried and weighed.

Aluminium and titanium, when present, remain in solution. Solutions of titanium alone, treated in a similar manner, gave no deposit.

The Determination of Iron.—C. Reinhardt† observes that in November 1884 he described a titration method for iron, which consisted in reducing the hot ferric chloride solution by stannous chloride, destroying the excess of stannous chloride by mercuric chloride, and then titrating with a dilute solution of permanganate containing manganese sulphate. This method the author has employed continuously since that date. The most important improvement on the original method that he has since made, consists in finding a reagent for the detection of the end reaction with permanganate, the yellow colour of the ferric chloride masking the pink colour of the permanganate. The author finds that by adding phosphoric acid the least excess of permanganate always produces a pure pink coloration, no matter how much iron is present, or how much mercurous chloride precipitate has been formed. The author describes the method of preparation of the various solutions and the general nature of the analytical methods. He shows that in very dilute solutions the reaction between stannous chloride and mercuric chloride is not complete. In standardising the permanganate solution the author makes use of potassium tetroxalate, the commercial salt being first purified by crystallisation from hot water. Whilst the acid solutions of the higher oxides of manganese and chromium are reduced by hydrogen peroxide, an acid iron solution is further oxidised, and not reduced. The oxidation is instan-

* *American Chemical Journal*, vol. x. p. 330.
† *Chemiker Zeitung*, vol. xxi. pp. 323-325.

taneous even in the cold, and is more easily effected by hydrogen peroxide than by any other oxidising agent.*

The Influence of Copper on the Determination of Iron.—According to Mr. T. W. Hogg,† the presence of copper interferes with the ordinary method of determining iron by reduction with zinc, and titration with potassium chromate. To obviate this, and also the presence of unexpelled hydrocarbons, a slight excess of potassium chlorate is added to the solution, which is then boiled, to ensure the solution of the copper. The solution is then reduced with sodium sulphite, and titrated with chromate solution.

An Ore-Pulverising Mill.—K. Zulkowsky ‡ describes an apparatus for pulverising ores for analytical purposes. The material is powdered between two agate plates, the upper of which is loaded with weights, and caused to rotate by an hydraulic motor. In this way it is possible to reduce chrome iron ore, and even spiegeleisen, to the finest powder.

III.—*FUEL ANALYSIS.*

The Determination of Sulphur in Coal.—R. Brullé § suggests the use of a long platinum boat provided with a cover, instead of the ordinary open dish. By using the covered vessel, about one third more sulphur is usually found in a coal than is the case if the oxidation is effected in an open dish, when a portion of the sulphur escapes as sulphurous anhydride.

IV.—*GAS ANALYSIS.*

Gas Testing and Sampling.—Mr. J. E. Stead ‖ describes a form of gas sampling apparatus which can be used in any position. The gas chamber is filled with mercury by raising the mercury reservoir

* *Comptes Rendus*, vol. cvii. p. 997.
† *Chemical News*, vol. lix. pp. 207-208.
‡ *Berichte der deutschen chemischen Gesellschaft*, vol. xx. p. 2664.
§ *Moniteur scientifique*, 4th Series, vol. iii. p. 230.
‖ *Journal of the Society of Chemical Industry*, vol. viii. pp. 176-178.

above it, and then the exit of the mercury draws in the gas of which a sample is required through a suitable nozzle as the mercury flows back to the reservoir.

In the most improved form of the gas testing device, the laboratory vessels are mounted on a turntable, so as to be easily connected to the eudiometer tube. In other forms, one or more absorption tubes are connected to the eudiometer tube through cocks. Instead of steel face plates connected by clamps, as used by Dr. Frankland, the author uses glass face plates slightly smeared with oil; these plates being connected to the tubes by cement.

STATISTICS.

CONTENTS.

	PAGE		PAGE
I. United Kingdom	403	VIII. France	416
II. Australasia	407	IX. Germany	417
III. Austria-Hungary	407	X. Japan	422
IV. Belgium	412	XI. Russia	422
V. Canada	414	XII. Spain	424
VI. China	414	XIII. Sweden	425
VII. Cuba	415	XIV. United States	427

I.—*UNITED KINGDOM.*

Mineral Statistics.—The production of coal in Great Britain in 1888 is officially reported to have amounted to 169,935,219 tons, against 162,119,812 tons in 1887, 157,518,482 tons in 1886, 159,351,418 tons in 1885, and 160,757,779 tons in 1884. The production in 1888 largely exceeded the quantity of coal mined in Great Britain in any previous year.

Iron Trade Statistics.—The following is a summary of the principal statistics given in the annual report of the Secretary of the British Iron Trade Association :—

Description.	1888.	1887.
	Tons.	Tons.
Production—		
Total production of pig iron in United Kingdom	7,898,634	7,441,927
Total production of hæmatite iron	3,180,555	3,064,837
Total production of basic iron	475,540	471,510
Total production of spiegeleisen and ferro-manganese	205,134	233,190
Total production of puddled bar	2,031,473	1,701,312
Total production of Bessemer steel ingots	2,012,794	2,064,403
Total production of Bessemer steel rails	979,083	1,021,847
Total production of basic steel	408,594	364,526
Total production of open-hearth steel ingots	1,292,742	981,104
Total production of ironstone under Coal Mines Act	8,635,032	7,569,918
Total production of coal	169,935,219	162,119,812
Stocks of pig iron in United Kingdom, December 31	2,588,708	2,778,684
Total deliveries of pig iron	8,106,135	7,317,067
Shipbuilding tonnage launched	904,329	577,327
Shipbuilding under construction at 31st December	811,468	439,335
Exports—		
Total exports of iron and steel from United Kingdom	3,966,984	4,143,028
Total exports of pig iron	1,036,177	1,158,174
Total exports of railroad iron and steel	1,020,264	1,011,779
Total exports of coal	26,968,462	24,460,967

Imports and Exports.—According to the Board of Trade Returns, the imports of iron ore, iron, and steel into the United Kingdom during 1888 were as follows:—

	Tons.
Iron ore	3,552,408
Bar, angle, bolt, and rod iron	113,362
Unwrought steel	12,058
Girders, beams, and pillars	60,313
Unenumerated	157,799

The exports during 1888 were as follows:—

	Tons.
Pig iron	1,036,177
Bar, angle, bolt, and rod iron	298,156
Railroad iron, all kinds	1,020,264
Iron rails	460
Steel rails	707,854
Wire, and manufactures of, except telegraph wire	64,144
Hoops, sheets, and boiler and armour plates	411,786
Tinplates and sheets	391,291
Cast and wrought iron	427,189
Old iron	144,827
Steel unwrought	153,532
Manufactures of steel or steel and iron combined	19,518
Total quantities of iron and steel	3,966,984
Total values	£26,372,755

Iron Ore Supply.—Mr. J. T. Smith * describes the iron ore supplies of the world, with special reference to the requirements of Great Britain. The chief countries with a good supply of iron ore are the United Kingdom, the United States, Germany, France, Sweden, Austria, and Spain. In Canada, Cuba, the South American Republics, India, and China the extent and character of the deposits have only been imperfectly determined.

Of the home ores there is practically an unlimited supply of Liassic iron ores, but it is doubtful whether the present supply of 2½ million tons of hæmatite can be maintained. The necessary supply must therefore be brought from abroad. The importation of iron ore into any country practically dates from 1866, and has risen to over 3¾ million tons into England in 1887. Germany has so developed her own ore production that she is not likely to demand large imports.

Spain and Sweden are the chief producers of Bessemer ore; Prussia's supply is too far from the coast; Elban ores are becoming scarce, but further supplies may be found in Algeria. The ores from the Bilbao and surrounding districts may be reckoned to last about twenty years. The ores in the South of Spain are practically untouched and unknown, but they are rich and suitable for the Bessemer process. The ores in the Gellivara district are both rich and good. The two iron mountains Luossavara and Kunumvara are computed to contain 270 million tons, so that these supplies will last for many years.

The future of the home demand is likely to be affected by new discoveries of indigenous ores and the development of the basic process; the former factor is, however, not likely to be of much account. The basic process at present has mostly been developed in Germany, where there are large supplies of suitable ore. France and Belgium, like Germany, will depend on the basic process, and will not have a great demand for Bessemer ores. There need be no fear for the near future about the supply of our own poorer and more impure ores.

As far as the United States is concerned only the group of iron-works on the Atlantic seaboard is, in the opinion of the author, likely to draw on the European supplies, and it would do so largely if the duty were removed. Mr. Hewett, in the discussion on this paper, dissented from this opinion, and thought that America would only use her own supplies, as they could be obtained so cheaply.

The price of iron ores largely affects the question, and this depends on the cost of mining and of carriage, the latter of which is a most

* Lecture delivered before the *British Iron Trade Association.*

important factor when the supply is drawn from distant sources. The great economies which have been and will be effected in transport will, of course, diminish this item, so that perhaps even Canadian ores may be imported successfully.

The use of magnetic separators for eliminating impurities may have a great effect on the supply if it can be made an assured success. In an appendix tabulated statements are given of the iron ore imports from various districts.

The Coal Question.—Mr. R. Price Williams,* draws attention to the decrease in the coal output of the Northern coalfields during the last five years, and considers that the maximum limit of coal production has been reached, and that henceforward it will continue to decline. At the average rate of increased production during the last twenty-two years, the 9294 million tons of available supply would be exhausted in about ninety-four years.

A considerable portion of the paper is devoted to the South Wales coalfield, and attention called to its large development. The other coalfields are also dealt with in detail, and, at the average rate of increase for the last twenty-four years, the following table gives the dates of exhaustion :—

	Years.
Northumberland and Durham	94
South Wales	79
,, ,, (Eastern Division)	46
Lancashire and Cheshire	74
Yorkshire, Derbyshire, and Nottingham	90
Warwickshire	53
Denbighshire and Flintshire	250
Scotland	92
United Kingdom	102

Particulars are given of the chief uses for which coal is consumed, and the various economies effected. For instance, at the time of the Coal Commission in 1871, nearly one-third of the total coal production was applied to iron and steel manufacture, while in 1887 the proportion was only a little more than 16 per cent., owing to the savings effected by the Bessemer and other processes. Finally, the author disapproves of taxes on exported coal, and hopes for further economies.

* *Journal of the Statistical Society*, vol. li. Feb. 19.

II.—*AUSTRALASIA.*

Mineral Statistics of New South Wales.—The production of coal in New South Wales steadily increases from year to year. The output in 1887 amounted to 2,922,497 tons, which was an increase of 92,322 tons over the output of 1886. The quantity shipped to inter-colonial ports in 1887 amounted to 1,077,270 tons. The iron industry of New South Wales makes no progress, being confined to one small rolling mill.

Mineral Statistics of New Zealand.—The output of coal in New Zealand in 1887 was 558,620 tons, an increase of 24,267 tons as compared with the previous year. The export of coal was 43,719 tons, and of coke 183 tons. Of manganese ore, 305 tons, valued at £895, was produced.

III.—*AUSTRIA-HUNGARY.*

Mineral Statistics.—W. von Lindheim * estimates the production of iron and steel in Austria-Hungary during 1888 to have been as follows:—

	Austria.	Hungary.	Totals.
	Tons.	Tons.	Tons.
Pig iron	565,272	196,334	761,606
Finished iron:—			
Merchant iron	195,594	69,006	264,600
Plates and sheets	43,182	10,033	53,215
Castings	65,086	21,256	86,342
Forgings, axles, and wheels	4,945	8,147	13,092
Rail accessories	13,235	4,784	18,019
Steel:—			
Ingots	261,552	93,486	355,038
Rails	90,107	58,900	149,007
Tires and axles	6,357	1,575	7,932
Merchant steel, plates, &c.	58,339	5,442	63,781

The total Austrian imports and exports of iron and steel amounted to 86,216 and 41,663 tons respectively.

* *Iron*, vol. xxxiii. p. 376.

The number of coke ovens in Austria in 1887 was 1591.* The workpeople employed in coal-mining numbered 75,102, and in iron ore mining 4106. At the various ironworks 9408 operatives were employed.

Metallurgical Statistics of Bohemia.—In 1887, in the kingdom of Bohemia, 326,216 tons of iron ore was produced. This was treated at 7 works with 10 blast furnaces, the out-turn being 125,339 tons of pig iron, of which 101,943 tons consisted of forge pig iron, and 23,396 tons of foundry pig iron. The iron industry afforded employment to 3996 men, 28 women, and 154 boys.

Manganese ore was produced to the amount of 6½ tons. Of the 15 plumbago mines, only 6 were at work, producing 12,033 tons of plumbago, and employing 731 men.

Lignite was raised from 190 mines, employing 17,882 men, 620 women, and 125 boys, the output amounting to 8,926,975 tons, of which 4,410,760 tons were exported. Coal was raised from 85 mines, employing 16,585 men, 1423 women, and 915 boys, the output being 3,509,212 tons, of which 51,172 tons were exported to Saxony and to South Germany. The production of coke amounted to 55,047 tons.†

Production of Petroleum.—Of the 257 petroleum mining works in Austria in 1887, 203 were at work.‡ These possessed 1345 shafts, 127 of which were being sunk, 545—40 per cent.—were yielding oil, and 673 were not in use. Besides these shafts there existed in Austria in 1887 1026 bore-holes, 189 of which were being put down, 283 were yielding oil by hand-working, and 309 by the aid of steam, whilst 245 were not in use.

The 203 active undertakings gave employment to 2890 men, 82 women, and 28 boys and girls. The output of petroleum was 478,176 tons, of the value of £141,715, the output showing an increase over that of the previous year of 10·93 per cent. in quantity, and 1·15 per cent. in value. There were 6 fatal, and 15 severe accidents. Of the fatal accidents, 1 was due to choke-damp, 1 to the breaking of the hoisting rope, 3 by explosions during blasting, and 1 to a fall.

Ozokerite was mined by 72 undertakings; the men employed num-

* *Oesterreichische Zeitschrift für Berg -und Hüttenwesen*, vol. xxxvii. p. 72.
† *Listy chemické* (Prague), vol. xiii. pp. 132-134.
‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxvii. p. 116.

bered 5554, the women 509, and the boys and girls 55. The production of paraffin amounted to 8047 tons of the value of £158,758, a diminution, as compared with the output in the previous year, of 15·26 per cent. in the quantity raised, and of 20·94 per cent. in its value.

The Petroleum Industry of Galicia.—In a paper read at the Mining Congress in Vienna, H. Höfer* stated that the petroleum industry of Galicia is some fifty years older than the American industry. The latter originated in 1859, whilst the Galician industry dates from 1810, when the first petroleum refinery was built. The importance of the oil industry to the district may be seen from the following figures. With a production of 200,000 barrels, the cost amounts to £28,000, and the profit remaining for the land owners to £90,000. The production in Galicia was as follows :—

In 1874	20,000 tons
„ 1878	24,500 „
„ 1882	46,100 „
„ 1886	75,000 „

The production of the last named year is valued at £300,000 for the crude oil, and at £600,000 for the refined oil.

From the geological configuration of the Carpathian Mountains, the presence of further petroleum fields may be expected, and in opposition to the general view that the oil is a product of the distillation of coal, petroleum may be regarded as a product of animal origin.

Accidents in Mines.—The number of accidents in the Austrian mines in 1887 included 148 which were of a fatal character, and 269 which though severe were not fatal. In 1886 the numbers were respectively 141 and 229. For every 1000 male workpeople there were 1·75 fatal and 3·19 severe accidents. In metallurgical works there were 6 fatal and 15 severe accidents in 1887, as compared with 6 fatal and 11 severe in the previous year. Of the total number of accidents the following occurred in colleries and iron ore mines :—

* *Berg- und Hüttenmännische Zeitung*, vol. xlvii. p. 374.

	Fatal.		Severe.	
	Total.	Per 1000 workmen.	Total.	Per 1000 workmen.
Coal mines . .	63	1·7	94	2·6
Lignite mines .	65	2·1	131	4·3
Iron ore mines .	7	1·7	20	5·0

The number of accidents, in relation to the quantities of ore and coal raised, was as shown in the following table:—

	For each Fatal Accident. Tons raised.		For each Severe Accident. Tons raised.	
	1886.	1887.	1886.	1887.
Coal . . .	123,748	140,024	49,657	53,390
Lignite . .	178,049	176,312	59,047	64,302
Iron ore . .	120,938	265,372	31,354	56,866

Over 44 per cent. of the accidents both in 1886 and in 1887 were due to falls of roof, &c. Accidents due to the hoisting arrangements formed the next most important item of the total percentage—19 per cent. in 1887 and 20 per cent. in 1886. Five per cent. of the accidents in 1887 and 1·6 per cent. in 1886 were due to fire-damp explosions. A further 4·1 per cent. of the accidents in 1887 occurred during blasting.*

Iron Trade Statistics of Hungary for 1887.—The official statistics † relating to the mineral production of Hungary in the year 1887, state the quantities of coal raised, and those of iron and steel manufactured, to have been as follows:—

* *Oesterreichische Zeitschrift fur Berg- und Hüttenwesen*, vol. xxxvii., p. 96.
† *Mittheilungen des k. ung. Ministeriums für Ackerbau*, vol. v. parts I., II.

	Quantities.		Value.	
	1886.	1887.	1886.	1887.
	Tons.	Tons.	Florins.	Florins.
Coal	859,197	786,408	4,345,476	3,788,041
Lignite . . .	1,567,614	1,723,440	4,657,145	4,998,150
Briquettes . . .	18,074	17,461	137,945	134,246
Forge Pig Iron . .	225,500	182,090	7,341,380	5,710,343
Foundry Pig Iron .	9,167	10,663	714,270	853,256
Pyrolusite . . .	2,192	963	19,977	10,665

The Iron Industry of Upper Hungary.—Dr. H. Wedding * gives an account of the present state of the iron industry of Upper Hungary. The iron ores are found in connection with trachytes and other eruptive rocks. The chief deposits of ore consist of spathic carbonate of great purity, which is changed near the surface, and sometimes to a considerable depth, into brown hæmatite. Red hæmatite and magnetite are also found, but in smaller quantities. These ore deposits mainly occur in the form of beds, inclined at a considerable angle, in clay slate. These beds occasionally widen out into stockwork-like deposits, such as are found between Dobschau and Rosenau. The Dobschau deposits are well known. The beds here sometimes reach 118 feet in thickness; the ore, containing 36 to 42 per cent. of iron and 2 to 4 per cent. of manganese, can be mined by open workings. At the Gömör mine, near Röeze, three brown hæmatite beds occur. They are respectively 40, 65, and 100 feet in thickness. The ore contains from 35 to 50 per cent. of iron.

Although Hungary still possesses upwards of sixty million acres of forest, the great consumption of charcoal by the blast furnaces, and the consequent distance from which the charcoal has now to be brought to the furnaces, have led to the increased use of coke. No true coal is found in Upper Hungary, and the coke has therefore to be imported; important deposits of lignite have, however, been found.

The production of pig iron has increased enormously since the beginning of this century, and the author gives a table, showing the annual output for each of the years 1823–1886, in the former of which it amounted to only 9985 tons, whilst in 1886 it reached 234,667 tons, 9167 of which was foundry and 225,500 forge iron. Before 1885 no

* *Stahl und Eisen*, vol. ix. pp. 186–192.

coke blast furnaces existed in Upper Hungary, now 28 per cent. of the total quantity is produced (at the Likér works) with this fuel. The largest coke blast furnace at the Likér works is 60 feet high, and has a capacity of 9712 cubic feet.

The production of Bessemer ingot iron, which amounted to 113 tons in 1868, reached 61,269 tons in 1885. In 1876 the production of open-hearth metal was only 1966 tons, but it rose so rapidly that in 1879 it reached 14,489 tons. In 1885 the production was 11,384 tons. In the same year 117,000 tons of rolled weld-iron ware was produced.

The Bessemer process on a small scale is in use at Zólyom (Altsohl) and Bikás. The ordinary Bessemer process is only in use at one works—that at Diósgyör—the annual production of which is about 25,000 tons of Bessemer ingots.

In conclusion the author gives brief accounts of a number of the ironworks of Upper Hungary.

IV.—*BELGIUM.*

Iron Trade Statistics.—The Belgian production of iron and steel* in 1888 was as follows:—

	Metric tons.
Foundry pig iron	52,884
Forge pig iron	614,357
Bessemer pig iron	159,743
Total	826,984
Rails and plates	114,853
Various descriptions	433,202
Total manufactured iron	548,055
Cast steel, ingots, &c.	223,638
Forged steel, rails, plates, &c.	188,588

The total production of coal in Belgium amounted to 19,185,181 tons.

Imports and Exports.—The following tables show the iron trade

* *Bulletin du ministère des travaux publics*, vol. xviii.

imports and exports into and from Belgium in 1888, the statistics for the preceding year being also shown : *—

Description.	Imports.		Exports.	
	1888.	1887.	1888.	1887.
	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.
Iron ore . . .	1,742,867	1,451,806	148,491	176,530
Ingot steel . . .	1,275	443	5,369	8,602
Steel rails . . .	249	166	62,661	48,910
Steel in sheets . .	2,516	2,339	24,818	26,397
Wrought steel . .	887	370	4,009	2,761
Pig iron . . .	212,814	141,462	9,801	11,701
Scrap iron . . .	25,211	17,831	3,608	11,048
Iron wire . . .	3,495	3,923	3,761	3,839
Iron rails . . .	559	81	10,435	29,351
Sheet iron . . .	1,341	866	44,833	19,795
Other iron . . .	8,112	5,383	247,968	252,726
Nails	551	559	13,242	10,482
Wrought iron . .	3,860	3,348	24,312	23,003
Castings . . .	933	1,116	21,107	24,733

The Coal Industry of Belgium.—The Belgian Minister for Mines has recently published † detailed statistics relating to Belgian coal mining. These statistics give the following details for each of the years 1861–1887 :—

Years.	Output.	Mines Working at a Profit.	Profit.	Mines Working at a Loss.	Loss.	Net Total Profit.
	Tons.		Francs.		Francs.	Francs.
1861	10,057,163	109	13,057,000	81	3,281,000	9,776,000
1871	13,733,176	106	17,115,000	62	2,825,000	14,290,000
1881	16,873,951	77	8,723,000	83	10,192,000	1,469,000 (Loss)
1887	18,378,624	90	10,829,000	50	2,088,000	8,741,000

* *Moniteur des Intérêts Matériels*, February 1889.
† *Comptes rendus mensuels*, January 5, 1889.

Year.	Average Profit per Ton.	Workpeople.		Sale Price per Ton.	Miscellaneous Extraordinary Expenses.
		Number.	Wages.		
	Franc.		Francs.	Francs.	
1861	0·97	81,675	725	10·94	14,372,000
1871	1·04	94,286	864	11·20	14,492,000
1881	(0·09 loss)	101,351	931	9·70	16,541,000
1887	0·48	100,739	815	8·04	9,558,000

The statistics show that in the twenty-seven years to which they relate Belgian coal mining has been a by no means profitable industry.

V.—*CANADA.*

Mineral Statistics.—Mr. E. Coste, director of the mineral statistics division of the Geological Survey of Canada, gives the following statistics:—

The coal production increased from 2,368,041 tons of 2000 lbs. in 1887 to 2,658,134 tons in 1888. The output of coke increased from 32,000 tons to 45,373 tons. The production of iron ore was 44,410 tons, valued at £139,393. Of manganese ore 1782 tons were produced, of petroleum 695,201 barrels, of limestone for iron flux 15,577 tons, and of charcoal 233,648 bushels.

The production of pig iron was 18,191 tons. The returns of wrought iron are very incomplete. The production is stated to have been 40,962 tons. This includes the out-turn of four rolling mills, one forge, and the Londonderry ironworks. Returns have not yet been received from six smaller works. The production of steel was 9508 tons.

VI.—*CHINA.*

Mineral Resources of China.—The mineral wealth of the Yunnan province is very great, iron and coal being included in the list of mineral products. The district lies between long. 100°–105° E., and lat. 23°–27° N.

Iron and coal have also been worked in the Kiang-su and An-Hui provinces. In the latter the manufacture of scissors forms an important trade. These provinces lie between long. 117°–118° E., and lat. 29°–34° N.

An excellent quality of iron and coal is found in the Shan-shi province, and some also occurs in the province of Shan-Tung. Both iron and coal are also found and worked in the Chih-li province, and the coal here is brought by rail to the treaty port of Tientsin. All these provinces lie close together.*

VII.—*CUBA.*

Mining Industry of Cuba.—According to the official statistics † four iron mines and three manganese mines were in operation in 1886, their production being 112,755 tons of iron ore, and 40 tons of manganese ore, all of which was exported to the United States or England. The number of miners employed in the iron ore mines was 393.

There were ten productive mines of asphalt, the total production being 2066 tons. One mine—La Felicidad—in the province of Matanzas produced 300 hectolitres (6600 gallons) of petroleum.

Manganese Mines in Cuba.—Mr. O. E. Reimer, United States Consul at Santiago de Cuba, has prepared a report descriptive of the manganese mines of Cuba. It appears from the report that 1300 tons of manganese ore have been shipped from those mines to the United States. The mines are divided into ten groups. The cost of the ore, laid down in Philadelphia, is said to be £3, 3s. 4d. per ton. According to Spanish law, the person discovering a mine, no matter on what land it is, whether Government or private property, submits to the provincial Government a plan of the probable extension of the mine. The Government then, if all is in conformity with details and fulfilling all the requirements of the law, grants a title to the mine. The title, however, does not take the surface property away from the owner. Later on, when the mines are to be worked, if no terms for the sale of the surface land can be agreed upon between the two parties, the Government appraises the land, and at this appraised value the owner of the surface land is obliged to sell to the owner of the mine. Land above

* *Indian Engineering*, vol. v. pp. 57–58, 179–180, 201–204.

† *Estadistica minera de España.* Madrid, 1888, pp. 177–192.

the mines, so far as discovered, is worth on the average from 12s. to 24s. per acre. The Spanish Government, under the date of June 30, 1887, by royal decree, ordered that manganese mines be exempt from all manner of taxes for twenty years. All material, machinery, tools, &c., to be used in the exploitation of manganese ore are free from import duty. Railway material, machinery, coal, &c., for mining purposes, are all free from import duty, and the mining railway is free from taxes for ninety-nine years. One serious drawback which so far has hindered the rapid development of this industry is the want of transporting facilities. The mines at present worked are some distance from the railroad, and in the rainy season it is extremely difficult for them to get their ore down to the railroads in carts and on mules.

VIII.—*FRANCE.*

Iron Trade Statistics.—The French production * of iron and steel during 1888 was as follows :—

	Metric tons.
Pig iron—	
Forge	1,306,930
Foundry	382,046
Total	1,688,976
Finished iron—	
Bars	723,633
Rails	538
Plates	109,668
Total	833,839
Steel—	
Bars	264,223
Rails	175,598
Plates	85,825
Total	525,646

The production of mineral fuel in France in 1888 amounted to 22,951,940 tons, of which 22,513,628 tons consisted of coal, and 438,312 tons of lignite.

A report upon the production of coal, iron, and other minerals in

* *Bulletin du comité des forges de France*, No. 248.

France during the last four years, has just been issued by the statistical commission appointed by the French Minister of Public Works. According to this report, the total quantity of coal raised during the year 1887 was 21,450,000 tons, or rather more than the total for 1883, which had up to that time been the highest ever known in France. Nevertheless, the consumption fell from 32,439,000 tons in 1883 to 29,619,000 tons last year, which is equivalent to saying that the imports were less by about 3,000,000 tons. This decrease is attributed by the commission to the crisis in the iron trade, the annual production of iron and steel, which reached 3,570,000 tons in 1883, having dropped to 2,712,000 tons in 1887. The almost complete cessation of railway enterprise is accountable for the decrease in the demand for steel, and whilst six years ago the iron and steel works consumed over 6,000,000 tons of coal, they did not consume more than 4,000,000 tons last year. This decrease is attributed by the report of the commission mainly to the stagnation in public and private enterprise, whilst the drop in prices, due at once to competition at home and abroad, and to improved modes of manufacture, has not brought the production up to its former level. Appended to this report are some tables, showing the total output of coal and the manufacture of iron in other countries during the same period, and it is worthy of remark, as regards the manufacture of iron, that while the totals for 1886 show a decrease in all the European countries, there was an increase of 1,665,000 tons in the United States. It may be added that the report of the commission gives the total output of coal for the whole world at 407,000,000 tons, and the manufacture of iron at 20,500,000 tons. The number of steam boilers, engines, &c., now in use throughout France has risen to 42,600 as against 29,000 ten years ago, the increase being due in a great measure to the fact that there are now 13,000 steam engines of one kind and another employed on French farms, compared with 4800 ten years ago.

IX.—*GERMANY.*

Iron Trade Statistics of Germany.—The following are the final official statistics * relating to the production of the coal and iron mines and iron and steel-works of the German Empire, including Luxemburg, during the year 1887 :—

* *Stahl und Eisen*, vol. ix. pp. 72-75.

	1886.	1887.
Iron Ore—		
Mines producing ore	629	615
Iron ore produced, tons	8,485,758	9,351,106
,, value per ton	3s. 6d.	3s. 7d.
Work-people employed	32,137	32,969
Pig Iron—		
Ironworks in blast	119	110
Charcoal iron produced, tons	32,893	29,845
Coke and mixed fuel iron, tons	3,495,765	3,994,108
Average value of pig iron per ton	£2, 0s. 4d.	£2, 1s. 4d.
Iron ore used, tons	8,948,946	10,312,356
Work-people employed	21,470	21,432
Total number of existing blast furnaces	285	271
Blast furnaces in blast	215	212
Time in blast, weeks	9,445	10,011
Foundry iron produced, tons	399,712	489,140
,, ,, value per ton	£2, 3s. 6½d.	£2, 6s. 0d.
Acid and basic Bessemer iron, tons	1,494,419	1,732,484
,, ,, ,, value per ton	£2, 1s. 0d.	£2, 1s. 3d.
Forge iron, tons	1,590,792	1,756,067
,, value per ton	£1, 17s. 0d.	£1, 18s. 9d.
Direct castings, tons	30,179	31,384
,, value per ton	£6, 13s. 7d.	£6, 1s. 10d.
Scrap and grain iron, tons	13,556	14,878
,, ,, value per ton	£2, 12s. 3d.	£2, 4s. 8d.

Iron and Steel Manufactures.

	1886.	1887.
(1.) *Iron Foundry.*		
Producing works	1,075	1,097
Work-people employed	45,813	48,668
Pig iron and scrap melted, tons	813,153	871,415
Tubes produced, tons	106,785	104,042
Other castings, tons	597,365	659,486
Average value of castings per ton	£8, 1s. 6d.	£8, 0s. 8d.
(2.) *Weld Iron and Weld Steel.*		
Cement steel for sale, tons	235	150
Blooms and puddled bars, tons	51,264	75,642
Rails and accessories, tons	13,348	9,812
Sleepers and accessories, tons	21,379	27,030
Railway axles, wheels, and hoops, tons	10,723	7,512
Shaped iron, tons	840,706	1,015,089
Plates and sheets other than tin-plate, tons	231,319	246,932
Tin-plate, tons	4,917	2,910
Wire, tons	188,172	185,032
Tubes, tons	14,187	17,486
Other iron and steel manufactures	39,360	37,383
(3.) *Ingot Metal.*		
Producing works	90	94
Workpeople employed	34,080	36,740
Ingots produced (for sale), tons	58,887	85,778

(3.) *Ingot Metal (continued).*—	1886.	1887.
Blooms, billets, slabs, &c. (for sale), tons	362,883	488,742
Average value of ingots, blooms, &c., tons	£3, 16s. 6d.	£3, 15s. 11d.
Rails and accessories, tons	391,635	456,219
Sleepers and accessories, tons	65,139	74,171
Railway axles, wheels, and hoops, tons	57,155	65,383
Shaped iron, tons	69,182	111.859
Plate and sheets, tons	69,915	88,791
Tin plate tons,		13,806
Wire, tons	221,838	259,591
Guns and projectiles, tons	8,511	11,682
Tubes, tons	5	10
Other ingot metal manufactures, tons	71,209	82,372
Average value per ton of ingot metal manufactures	£6, 2s. 8d.	£5, 18s. 7d.

Production of Coal.

	1886.	1887.
Coal, tons	58,056,598	60,333,984
,, value	£15,086,385	£15,553,865
,, value per ton	5s. 2½d.	5s. 2¾d.
Work-people employed	217,581	217,357
Lignite, tons	15,625,986	15,898,634
,, value	£2,011,113	£2,010,069
, value per ton	2s. 6½d.	2s. 6d.
Work-people employed	29,668	29,408

Work-people Employed.

	1886.	1887.
Iron ore mining	32,137	32,969
Blast furnaces	21,470	21,432
Iron manufacture	130,858	138,176

The following are the preliminary official returns of the production of coal, iron ore, and iron in Germany and Luxemburg in the year 1888:*—

	1888.	1887.
	Tons.	Tons.
Coal	65,321,834	60,333,984
Lignite	16,541,977	15,883,634
Iron ore	10,664,789	9,351,106
Charcoal pig iron	19,748	23,150
Coke pig iron	4,238,723	3,931,263
Castings	779,904	706,557
Weld iron	1,547,357	1,513,058
Ingot iron	1,785,354	1,688,809

* *Stahl und Eisen*, vol. ix. p. 445.

Pig Iron.—According to the statistics collected by the German Iron and Steel Society,* the production of pig iron in Germany in 1888, apart from charcoal iron, and scrap, was as follows:—

	1888.	Per Cent. of Total Production.
	Metric Tons.	
Forge iron and spiegeleisen . .	2,064,016	48·8
Acid Bessemer iron	395,878	9·3
Basic Bessemer iron . . .	1,253,308	29·5
Foundry iron	516,282	12·4
Totals	4,229,484	100·0

The production of pig iron in Germany in 1887 was 4,023,953 tons.†

Imports and Exports.—The following table shows the imports and exports of pig iron into and from Germany and Luxemburg in 1888, as calculated by the German Iron and Steel Society:—

	Imports.	Exports.
	Metric Tons.	Metric Tons.
Pig iron.	216,957	144,250
Scrap iron	7,484	28,476
Totals .	224,441	172,726

These totals show a net increased importation of pig iron in 1888 of 51,715 tons, as compared with the statistics of the previous year.†

The Iron Industry of Upper Silesia.—In a paper read before the Breslau Meeting of the German Institute of Engineers, Dr. B. Kosmann discussed the progress made in the past by the Iron Industry of Upper Silesia. Although the number of furnaces in blast has diminished in recent years, the average output of each furnace is now 41½ per cent. higher than was the case ten years ago. With regard to

* *Stahl und Eisen*, vol. ix. p. 153.
† *Ibid.*, vol. ix. p. 329

the future of the industry, the author points out that Upper Silesia is rich in coal, the probable quantity capable of being mined in the chief coalfield being estimated as at least 3,200,000,000 tons, whilst the present output is only 12,000,000 tons. A considerable portion of this coal will yield a good furnace coke when treated by itself, and the methods for treating coal of less value for the coking purposes have made rapid developments during recent years.

The most important ore found in this district is a brown iron ore which contains from 26 to 32 per cent. of metallic iron, a considerable quantity of silica being also present. The ore, however, contains a variable quantity of zinc, and consequently presents certain difficulties in respect to its blast furnace treatment. To avoid these, and to produce a pig iron of better quality than could be obtained if this ore was smelted alone, large quantities of other ores are now imported into the district, and are smelted in admixture with the brown iron ore. The author glances at the progress made in recent years by the steel industry of the district. Bessemer plant was erected at the Friedenshütte in 1884, similar plant having been in work at the Königshütte since 1872.

Iron Trade Statistics of Lorraine.—The following official statistics * show that very rapid progress has been made of late years in the iron industry of Lorraine :—

	Production in Tons.		
	1872.	1880.	1888.
Iron ore	677,659	995,954	2,805,263
Coal	290,205	508,085	689,135
Pig iron	214,032	287,734	543,098
Castings	15,678	16,314	12,351
Weld-iron and steel	141,266	161,395	155,797
Ingot-iron and steel	3,001	379	106,890
Totals	1,341,841	1,969,861	4,312,534

The number of workmen employed in 1872 was 10,762, whilst in 1888 the number was 14,643.

* *Stahl und Eisen*, vol. ix. p. 328.

X.—*JAPAN.*

Imports of Rails.—In 1886 Japan received from Great Britain 56,590 tons of rails, and from Germany 33,945 tons; in 1887 the quantities were 64,463 and 63,771 tons respectively.*

Coal in Japan.—In a letter † from the secretary of the Yokohama General Chamber of Commerce, it is stated that the most productive coal mines are the Takashima, Katatsu, and Müki mines in the south, not far from Nagasaki, and the Poronai mines on the island of Yesso. There are also other mines on the island of Kiushiu and in the Province of Echigo. At a rough estimate, the production may be placed at fully one million tons, viz :—Takashima mines about 370,000 tons per annum, Müki mines 240,000 tons, and the Poronai mines about 80,000 tons. The remaining 310,000 tons come from other mines. The Takashima mines produce the best coals, the others are inferior in quality. The exports were—

Year.	Tons.	Value. Dollars.
1882	327,240	1,197,053
1883	391,944	1,373,570
1884	522,211	1,828,263
1885	580,689	1,975,965
1886	670,863	2,208,548
1887	704,935	2,337,804

XI.—*RUSSIA.*

Mineral Statistics.—The Russian official statistics for 1886 have recently been issued. The report, which covers 340 pages, is edited by S. Kouleebin. The production of pig iron amounted to 515,625 tons, that of wrought iron to 351,783 tons, and that of steel to 234,317 tons. There were also produced 61,520 tons of iron castings, 1399 tons of enamelled ware, and 50,172 tons of steel and iron work. The Russian mines produced :—Coal 4,434,816 tons, manganese ore 72,097 tons. The production of naphtha amounted to 1,911,248 tons.

Manganese Ore in Transcaucasia.—A report has been published by Professor Kotsovsky, who was sent by the Russian Minister of

* *Industries*, vol. v. p. 445.

† *Japan Mail*, October 14, 1888.

Mines to examine the deposits of manganese in Transcaucasia. The ore contains as much as 55 per cent. of manganese, but is not remarkable except for the extent of the Tchiatoury beds. Better systems of working and transport are required.*

Coal in Russia.—The Belgian consul at Warsaw† states that the production of coal is the only industry which has really progressed in Russia within the last few years. The coal mines are mainly found in the Dombrowa basin, near the Prussian Silesian frontier. There are altogether twenty-eight collieries, employing 7824 horse power and 9572 men. The average thickness of the beds is from 50 to 60 feet.

Coal Imports.—According to a report‡ published by the Russian Minister of Finance, nearly 800,000 tons of coal were imported into St. Petersburg in 1888, the amount being about the same as the total quantity delivered during the previous three years. At Odessa the imports reached about 180,000 tons, which was nearly as much as the quantity of foreign coal landed at Riga. The next in order of the coal importing ports were Libau, 58,000 tons; Revel, 55,000 tons; and Sebastopol, 34,000 tons. Owing to the severe winter of 1887–8 putting a stop to coal mining in South Russia, the importations of coal into Odessa rose from 45,000 tons in 1887 to 180,000 tons in 1888. Many of the pits filled with water in the spring, and the railways were also disorganised, but on the whole the tendency is towards an increased output, which, it is said, will tend to exclude British coal from the Black Sea in a few years.

Exports of Petroleum.—The exports of petroleum from Baku in 1888 amounted to 29,032,210 poods. The petroleum in stock at Baku at December 31, 1888, was 1,389,590 poods. The American petroleum barrel holds 9 poods of refined oil. §

* *Iron*, vol. xxxiii. p. 256.
† *Industries*, vol. vi. p. 404.
‡ *Engineering*, vol. xlvii. p. 261.
§ *Iron Age*, vol. xliii. p. 440.

XII.—*SPAIN.*

Mineral Statistics.—The Spanish official mineral statistics* for the year 1886 have recently been issued. They show that there were 526 productive iron mines, 3 productive manganese mines, 502 collieries, and 54 lignite mines.

The production of iron ore amounted to 4,166,946 tons, valued at £569,900. There were at the mines 30 steam engines, having a total horse-power of 518. The production of manganese ore amounted to 400 tons, valued at £291.

The production of coal amounted to 977,559 tons, valued at £327,467. The collieries were equipped with 78 steam engines, having, a total horse-power of 2570. The production of lignite was 23,873 tons, valued at £15,805.

There were in 1886 thirty-three ironworks in operation. Their output amounted to 147,703 tons of pig iron, 1524 tons of wrought iron obtained by direct processes, and 56,204 tons of wrought iron obtained from pig iron. The amount of iron ore smelted was 392,036 tons. Of steel 20,261 tons was produced. There were 24 blast-furnaces, 74 reverberatory furnaces, 76 forges, 18 cupolas, and 80 fineries.

Iron Industry of Bilbao.—In 1888 the production of pig iron in the valley of the Nervion amounted to about 200,000 tons, from seven blast furnaces. Of this total the two furnaces of the Company of the Altos Hornos produced 60,000 tons, the three furnaces of the San Francisco Company produced 60,000 tons, and the two furnaces of the Viscaya Company produced 80,000 tons. The total consumption of iron ore amounted to 414,000 tons, representing an average yield of 49 per cent.

Although the Altos Hornos works converts almost all its pig iron into wrought iron and steel, the other two works in 1888 sold all their output, the exports of pig iron from Bilbao in 1888 amounting to 135,200 tons.

The production of pig iron rapidly increases from year to year, the output having been 150,000 tons in 1886, 170,000 tons in 1887, and 200,000 tons in 1888.†

According to other statistics, the blast furnaces of the Bilbao district

* *Estadistica minera de España.* Madrid, 1888.

† *Mémoires de la société des ingénieurs civils,* vol. xlii., p. 260.

oduced in 1888 135,200 tons of pig iron. The quantities sold by e undermentioned works were as shown in the table :—

Works.	Sold for	
	Home use.	Exports.
	Tons.	Tons.
Altos Hornos	8,500	13,400
San Francisco (Mudela)	14,800	25,300
La Sociedad Viscaya	26,600	47,200

The last named works is the most recently established of the ree.*

The total quantity of iron ore exported from the port of Bilbao in 88 amounted to 3,631,593 metric tons, against 4,198,696 tons in 87. Of the exports in 1888 Great Britain received 2,481,335 tons.

XIII.—*SWEDEN.*

Iron Trade Statistics.—The official statistics relating to the redish iron trade for the year 1887 have recently been published. ley are as follows :—

Iron Ore.—From 655 mines 902,000 tons of iron ore were raised, sides which 973 tons of bog and lake ores were also produced, the oduction of ores from deep mines showing an increase of 34,633 tons er the production of the previous year, whilst the output of lake and g ores had diminished by 3917 tons. Besides the 655 producing nes there were 280 other mines from which no ore was being sed. The number of work-people employed was 6337. The yield the more important districts is shown in the following table :—

District.	Mines.	Iron Ore Raised.
		Tons.
Örebro	89	245,300
Kopparberg	93	220,400
Vestmanland	63	212,200
Vermland	61	104,700
Upsala	20	64,709

* *Bilbao Maritimo y Comercial*, January 1889.

The production of the Gellivara iron ore field was only 2200 tons.

Pig Iron.—The number of blast furnaces in blast in Sweden in 1887 was 164, and the production of pig iron amounted to 456,625 tons, 4985 of which were castings, an increase of 14,248 tons as compared with the production of 1886. The production of some of the chief districts was as follows:—

District.	Blast Furnaces in Blast.	Pig Iron Produced.
		Tons.
Örebro	49	115,300
Kopparberg	31	106,900
Vermland	23	59,940
Gefleborg	20	55,000
Vestmanland	15	46,800
Jönkoping	1	365

The largest production of any one works was that of the Domnarfvet Works in the Kopparberg District. This amounted to 25,520 tons—17·54 tons per blast furnace and per day.

Rails.—The rolling mills at the Domnarfvet works produced in 1887, 8462 tons of rails.

Foundries.—The production of pig iron castings, other than direct castings, amounted to 24,195 tons. Besides these castings 1373 tons of open hearth castings were also made.

Weld Iron.—The production of the 529 hearths and other furnaces was 221,150 tons of weld iron, 201,570 of which was produced in Lancashire hearths.

Ingot Metal.—The ingot metal produced by the Bessemer process amounted to about 68,200 tons, and by the open-hearth process to about 41,900 tons. There were sixteen Bessemer works in Sweden in 1887, one of which was not at work; and seventeen open-hearth steel works, two of which were lying idle.

Iron Trade Exports.—The exports of iron ore from Sweden in 1888 amounted to 117,350 tons, as compared with 41,985 tons in 1887, and 19,288 tons in 1886.

The exports of pig iron and ballast iron amounted to 49,095 tons, about 200 tons less than in 1887.

The exports of ingot iron ingots reached 6459 tons in 1888, more than double the quantity exported in 1886.

The quantity of blooms and puddled bars exported also showed a

ery considerable increase, having being 14,536 tons in 1888 as against 831 tons in 1885.

The exports of shaped iron, other than rails, amounted to 187,775 ons, about 6000 tons less than in 1887.

There was a slight increase in the exports of malleable iron scrap, ut the exports of wire iron diminished from 5590 tons in 1887 to 942 tons in 1888. The exports of sheets were 5700 tons, an increase f 72 per cent. in the last four years. The exports of machines, other han steam-engines, were of the value of £134,270, whilst the imports eached £442.

Production of Open-Hearth Steel.—Odelstjerna* publishes the ollowing summary, showing the progress made by the open-hearth teel industry in Sweden during the years 1884–1887 :—

	1884.	1885.	1886.	1887.
Number of Works	14	18	18	19
Number of open-hearths	20	26	27	28
Total capacity of the open-hearths, tons	70	103·5	112	137·5
Increase in capacity, per cent.	...	47·9	8·3	22·3
Production of ingots, tons	23,699	28,914	33,463	40,461
Increase in the production of ingots, per cent.	...	22	16	21
Production of castings, tons	318	593	818	1373
Increase in the production of castings, per cent.	...	86	55	68
Number of furnaces taking 1½ ton charges	...	...	1	1
" " 2 "	4	6	4	2
" " 2½ "	4	4	3	5
" " 3 "	...	...	...	2
" " 3½ "	2	1	2	...
" " 4 "	5	5	7	3
" " 4½ "	3	2	2	2
" " 5 "	...	2	2	4
" " 5½ "	1	2	2	1
" " 6 "	1	2	1	2
" " 8 "	...	2	3	2
" " 9 "	...	...	...	1
" " 10 "	...	...	...	3

XIV.—*UNITED STATES.*

The American Iron Trade.—The following is a summary of the principal statistics given in the Annual Statistical Report of the American Iron and Steel Association † for 1888 :—

* *Jernkontorets Annaler*, vol. xliii. † Presented to the members, April 1, 1889.

Iron Trade Statistics of United States, 1887–1888.

	1887.	1888.
Production of pig iron, net tons of 2000 lbs.	7,187,206	7,268,507
Production of spiegeleisen, included in pig iron, net tons	47,598	54,769
Production of bar, rod, hoop, skelp, and shaped iron, net tons	1,917,403	1,819,585
Production of plate and sheet iron, except nail plate, net tons	477,056	469,312
Production of bar, rod, hoop, skelp, and shaped steel, net tons	528,989	772,017
Production of plate and sheet steel, except nail plate, net tons	198,702	213,694
Production of cut nails and spikes, kegs of 100 pounds	6,908,870	6,493,591
Production of steel nails only, kegs of 100 pounds	3,489,292	4,323,484
Production of all rolled iron, including iron nails and excluding rails, net tons	2,565,438	2,397,402
Production of all rolled steel, including steel nails and excluding rails, net tons	902,156	1,201,885
Production of Bessemer steel rails, net tons	2,354,132	1,552,631
Production of open-hearth steel rails, net tons	19,203	5,261
Production of iron rails, net tons	23,062	14,252
Total production of rails, net tons	2,396,397	1,572,144
Production of street rails, included above, net tons	57,362	50,345
Production of Bessemer steel ingots, net tons	3,288,357	2,812,500
Production of open-hearth steel ingots, net tons	360,717	352,036
Production of crucible steel ingots, net tons	84,421	78,713
Production of blister and "patented" steel, net tons	6,265	4,124
Production of all kinds of steel, net tons	3,739,760	3,247,373
Production of iron blooms, net tons	43,306	39,875
Value of imports of iron and steel, dollars	56,420,607	42,308,256
Value of exports of iron and steel, dollars	16,235,922	19,578,489
Imports of iron ore, statute tons	1,194,301	587,470
Home production of iron ore, statute tons	11,300,000	12,062,530
Production of anthracite coal, statute tons	35,273,442	38,909,000
Total domestic production of coal, statute tons	110,727,906	123,674,771
Iron and steel ships built in the fiscal year ended June 30	29	43
Miles of new railroad completed	13,080	7,106
Total number of miles of railroad, December 31	151,066	158,172

The statistics have been compiled by Mr. J. F. Swank, the General Manager of the Association.

The total production of pig iron in the United States in 1888 was 6,489,738 statute tons, the largest yearly production ever attained in the country. Classified according to the fuel used, the production was as follows :—

Fuel used.	Tons of 2000 lbs.
Bituminous coal	4,743,989
Anthracite and coke	1,648,214
Anthracite alone	277,515
Charcoal	598,789
Total	7,268,507

Imports and Exports.—The United States Bureau of Statistics publishes the following statistics showing the iron trade imports into the United States in the calendar year 1888 as compared with those of the preceding year:—

Imports of Iron and Steel, Statute Tons.

Description.	1888.	1887.
Iron ore	587,470	1,194,301
Pig iron	196,892	467,532
Iron scrap and old rails	44,799	313,405
Steel scrap	9,179	26,532
Bar iron	31,745	36,219
Iron rails	21	241
Steel rails	60,939	137,588
Cotton ties	30,305	21,675
Hoop, band, and scroll iron	256	69
Steel hoops, sheets or plates	23,411	24,004
Steel blooms, billets, slabs, or bars	103,687	310,551
Sheet, plate and taggers iron	6,239	7,153
Tin plates	297,862	283,836
Wire rods	101,812	149,368
Wire and wire rope	3,169	2,899
Anvils, axles, and forgings	1,177	1,316
Chains	829	914
Totals	912,322	1,783,282

Furnaces in Blast.—Of the 178 anthracite blast furnaces in existence in the United States at January 1, 1889, only 107 were in blast, the condition of the various furnaces being as shown in the following table:—

States.	Total number of Furnaces.	Number in Blast.	Capacity per Week. Tons.	Number out of Blast.	Capacity per Week. Tons.
New York	24	12	3,828	12	3,442
New Jersey	13	5	2,143	8	2,392
(Spiegeleisen)	3	3	264	0	0
Pennsylvania:					
Lehigh Valley	44	27	10,036	17	5,413
(Spiegeleisen)	1	1	55	0	0
Schuylkill Valley	38	23	7,900	15	3,879
Susquehanna Valley	22	12	4,679	10	2,266
Lebanon Valley	16	14	6,752	2	988
U. Susquehanna Valley	17	10	3,069	7	1,606
Totals	178	107	38,726	71	19,986

The condition of the furnaces using bituminous coal or coke as fuel was as follows *:—

Coal and Coke Furnaces in the United States.

States.	Total Number of Furnaces.	Number in Blast.	Capacity per Week. Tons.	Number out of Blast.	Capacity per Week. Tons.
New York	3	1	1,118	2	2,000
Pennsylvania:					
Pittsburgh district	19	19	20,000	0	0
(Spiegeleisen)	1	1	420	0	0
Shenango Valley	19	16	11,270	3	1,740
Juniata and Conemaugh Valley	18	11	5,691	7	2,460
(Spiegeleisen)	1	0	0	1	430
Youghi. Valley	5	4	1,605	1	600
Miscellaneous	4	4	2,030	0	0
Maryland	2	1	250	1	120
West Virginia	6	3	2,440	3	538
Ohio:					
Mahoning Valley	14	11	9,380	3	2,374
Central and Northern	18	11	7,958	7	4,448
Hocking Valley	14	8	2,989	6	1,340
Hanging Rock	13	7	1,730	6	1,045
Indiana	2	2	383	0	0
Illinois	12	10	11,485	2	1,525
(Spiegeleisen)	1	1	725	0	0
Wisconsin	4	3	1,660	1	700
Missouri	6	1	568	5	2,130
Colorado	1	1	490	0	0
The South:					
Virginia	11	8	3,887	3	2,117
Kentucky	4	4	1,320	0	0
Alabama	21	18	10,360	3	1,300
Tennessee	11	11	5,262	0	0
Georgia	2	1	501	1	260
Totals	212	157	103,522	55	25,227

At January 1, 1888, there were in blast 143 bituminous coal and coke furnaces, with a weekly capacity of 83,101 tons; 118 anthracite furnaces, with a weekly capacity of 38,206 tons; and 65 charcoal furnaces, with a weekly capacity of 11,315 tons.

The following table shows the condition of the charcoal furnaces at January 1, 1889:—

* *Iron Age*, vol. xliii. pp. 57-95

Charcoal Furnaces in the United States.

States.	Total Number of Furnaces.	Number in in Blast.	Capacity per Week. Tons.	Number out of Blast.	Capacity per Week. Tons.
New England . .	14	8	605	6	495
New York . .	10	3	376	7	570
Pennsylvania . .	23	5	450	18	624
Maryland . . .	8	4	347	4	250
Virginia . . .	23	3	166	20	780
West Virginia . .	3	0	0	3	165
Ohio	18	8	585	10	710
Kentucky . . .	2	2	208	0	0
North Carolina . .	2	1	90	1	80
Tennessee . . .	9	4	1,060	5	870
Georgia . . .	2	0	0	2	114
Alabama . . .	10	8	1,579	2	468
Michigan . . .	25	12	3,813	13	3,010
Minnesota . . .	1	0	0	1	190
Missouri . . .	4	2	557	2	320
Wisconsin . . .	10	4	1,455	6	810
Texas . . .	2	1	120	1	146
California . . .	1	0	0	1	220
Washington Ter. .	1	1	270	0	0
Oregon . . .	1	1	275	0	0
Totals . .	169	67	11,956	102	9,822

Production of Coal.—Mr. C. A. Ashburner has officially reported that the total production of coal in the United States in 1888 amounted to 145,363,744 tons of 2000 lbs. as compared with 129,975,557 tons in 1887. The value of the coal raised in 1888 was 208,129,806 dollars, whilst that raised in the previous year was of the value of 182,556,837 dollars.

Lake Superior Iron Ore Mines.—The Marquette *Mining Journal* estimates the total production of the Lake Superior iron ore mines in 1888 at 5,000,000 tons, or about 300,000 tons in excess of their output in 1887. In the season of 1888 fourteen of the larger mines shipped by the Lake 2,658,066 statute tons of ore, or more than half the total quantity water-borne.

By ranges, the shipments were as follows :—

Range.	1888.	1887.
Menominee	1,111,220	1,154,110
Marquette	1,815,402	1,755,328
Gogebic	1,223,334	1,081,872
Vermillion	433,607	302,081
Totals	4,583,563	4,383,391

Exports of Petroleum.—The quantity of petroleum exported from the oil regions of the United States in 1888 amounted to 26,470,654 barrels of forty-two gallons, the stock on hand at December 31, 1888, being 18,595,474 barrels, the decrease in stocks as compared with the previous year being 9¾ million barrels.* Of the 26 million barrels exported from the oil regions about 10 millions were consumed in the United States, the remainder being exported to foreign countries. The actual exports of crude and refined oil, reduced to gallons of crude oil, was as follows in 1887 and 1888:—

Shipping Port.	1887.	1888.
	Gallons.	Gallons.
New York	479,654,495	471,627,848
Philadelphia	193,776,717	166,380,036
Baltimore	12,741,061	6,836,325
Boston	5,609,544	4,693,722
Perth Amboy	22,434,260	21,611,707
St. Louis (Rail to Mexico)	1,683,540	2,000,000
Totals	715,899,617 †	673,149,638

The shipments of refined oil from New York alone amounted to 319,228,758 gallons in 1888, as compared with an export of 325,408,772 gallons in the previous year. The exports to Great Britain diminished by 2¼ million gallons, whilst those to Germany increased by 13½ millions. There was, however, a diminution in the total exports of 6,000,000 gallons.

The Iron Industry of the Southern United States.—In an

* *Iron Age*, vol. xliii. p. 440.

† 715,902,617 in the original.

article contributed to the "Mineral Resources of the United States" for 1888, Mr. J. M. Swank describes the rapid progress of the iron industry of the Southern States of the American Union. At July 1, 1888, there had been erected in the States south of the Potomac and Ohio rivers since the commencement of 1886, twenty-one large and well-equipped blast furnaces, fifteen of which had been completed in 1888; eighteen of these furnaces were to use coke, and the other three charcoal as fuel. Ten coke furnaces and four charcoal ones were in the course of erection at the date referred to. All these furnaces are of large capacity. The total number of completed blast furnaces in the States south of the Potomac and the Ohio, not including Missouri, amounted to 109, 57 of which were coke furnaces and 52 charcoal. Two other blast furnaces have since been completed. It was at one time feared that the supply of suitable coke from the southern coal-fields would prove insufficient. This has, however, proved not to be the case, as the supply of coke has kept pace with the demand, whilst the quality has improved.

In 1887 two small Bessemer steelworks were completed, and on February 27, 1888, the first steel ever made in Alabama was produced at the works of the Henderson Steel Company, Birmingham, a new open-hearth being used.

Numerous foundries and machine shops have been erected at Nashville, South Pittsburgh, Chattanooga, Knoxville, Birmingham, Anniston, and elsewhere in the Southern States.

The Birmingham District, United States.—The total daily output of the blast furnaces of this district amounts to about 1600 tons. In 1888 the quantity of coal mined in this district is estimated at 2,225,000 tons. In 1870 the output of coal in the whole state of Alabama was but 11,000 tons, only a very small part of which was derived from the neighbourhood of Birmingham.*

The Iron Industry of the Western United States.—The rapid progress that has been made in the last few years in the production of pig iron in the Western States of the American Union has to a great extent been overlooked. From the following tables it will be observed that although the total number of blast furnaces in the States named has decreased from 139 in 1885 to 134 in 1888 the output of pig iron has nearly doubled within the same period: †—

* *Iron Age*, vol. xliii. p. 194. † *Ibid.*, xliii. p. 203.

Blast Furnaces.

States.	1885.	1886.	1887.	1888.
Ohio	81	75	77	77
Indiana	2	2	2	2
Illinois	16	16	16	16
Michigan	27	26	27	27
Wisconsin	13	14	14	12
Totals	139	133	136	134

Production, Tons of 2000 *lbs.*

States.	1885.	1886.	1887.	1888.
	Net Tons.	Net Tons.	Net Tons.	Net Tons.
Ohio	553,963	908,094	975,539	1,103,818
Indiana	6,634	16,660	13,211	15,260
Illinois	327,977	501,795	565,453	579,307
Michigan	143,121	190,734	213,543	213,251
Wisconsin	24,632	65,933	133,508	116,037
Totals	1,056,327	1,683,216	1,901,254	2,027,673

The Cost of Blooms and Billets.—On page 696 of the "Tariff Statements" of the Finance Committee of the Senate of the United States are the following statements of the cost of converting pig iron into Bessemer ingots, and of the latter into blooms and billets:—

Cost of Bessemer Ingots.

	Dollars.
Waste of pig iron and new material	2·80
Labour	1·12
Fuel	0·35
Refractory materials	0·15
Moulds and stools	0·24
Maintenance and working expenses	0·75
Total	5·41

Cost of Bessemer Blooms from Ingots.

	Dollars.
Waste of metal	0·65
Labour	0·63
Fuel	0·25
Maintenance and working expenses	0·55
Total	2·08

Cost of Blooms from Pig Iron.

	Dollars.
Pig iron to ingot	5·41
Ingot to bloom	2·08
Total	7·49

Cost of Bessemer Billets.

	Dollars.
Waste of metal	0·90
Labour	1·60
Maintenance	0·45
General maintenance of works and working expenses	1·10
Fuel	0·29
Total	4·34

Cost of Billets from Pig Iron.

	Dollars.
Pig iron to ingot	5·41
Ingot to bloom	2.08
Bloom to billet	4·34
Total	11·83

No mention is made of the locality to which these statements refer.

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INDEX.

1889.

A

Accidents in Austrian mines, 409.
Accounts of Institute, 7.
Adams' coke-oven bottom, the, 263.
Adamson, Daniel, remarks on proposing adoption of Report of Council, 7; on acknowledging vote of thanks, 11; on testing machines, 200.
Aikman, C. M., on basic slag as manure, 349.
Ainslie, W. G., remarks on offering thanks to Council, 11.
Air, compressed, for blast in cupola furnaces, 316; compressing machinery at collieries, 291; of coal mines, the, 281.
Åkerman, R., on the proportion of ash and phosphorus in charcoal, 261.
Alabama, notes by Major Burke on the new iron region of, 205.
Alaska, coal in, 257.
Alloys of nickel and steel. See *Riley, J.*
American blast furnace practice, 308; charcoal blast furnace, an, 305; engineers, visit of, to Europe, 17; iron trade, statistics of, 427.
Analysis, chemical, of iron and steel, 391; of coal, 251.
Annual meeting, opening of, 1.
Anthracite and coke in the blast furnace, 295.
Appliances, mining, improvements in, 272.
Application of electricity to mining, 273.
Armour-plate trials, 364.
Armstrong, W., on signalling from mining cages, 276.
Arsenic, influence of, on the determination of phosphorus, 396.
Artificial production of chrome iron ore, 236.
Asbestos, firebricks of clay and, 249.
Ash and phosphorus in charcoal, proportion of, 261.
Ashburner, A., on the coal industry of the United States, 431.
Ashton, T., on the rolling mills at Pittsburgh, 335.
Austria-Hungary, mineral statistics of, 407.
Autumn meeting, 1888, 5.

B

Babu, L., on the petroleum of Galicia, 264.
Baedeker, D., on the Krupp Steelworks at Essen, 345.
Bagnall, W. G., on a steel sleeper, 362.
Ball, Edwin J. (and Arthur Wingham), *paper* "On the influence of copper on the tensile strength of steel"—Introduction, 123; views of different authorities, 123; experiments undertaken, and composition of basic steel used, 123; method employed,

124; analysis of metal obtained, 124; percentages of carbon and copper, 124; table showing copper and carbon present and tensile strength, 125; diagram of carbon in relation to tensile strength, 125; results showing that copper increases the tensile strength of iron, 126; fracture, 126; forging tests, 126; order of elimination of metalloids, 127; results, 127. *Discussion:* Stubbs, F., 129; Bauerman, H., 129; Ball, Dr., 130.
Barlow-Massicks, T., vote of thanks to Mr. Hewitt, 36.
Barus, Dr., on a new pyrometric method, 250.
Bascom, J. D., on a long wire rope, 357.
Basic open-hearth process, 341; slag as manure, 349; steelworks of the Graz Southern Railway, 342.
Batho furnace, 341.
Bauerman, H., on the influence of copper on the tensile strength of steel, 129; on thermal chemistry, 173.
Bayonets and swords, tests for proving, 378.
Beaurain-Vautherin, on firebricks of clay and asbestos, 249.
Belelubsky, Prof., on the use of ingot iron for bridges, 365.
Belgian imports and exports, 412; iron and steel production of, 412; coal industry of, 413.
Bellite, 285.
Bell, Sir Lowthian, election of, as vice-chairman of Imperial Institute, 6; remarks on proposing vote of thanks for President's address, 31; on basic open-hearth steel, 108, 111; on thermal chemistry, 167, 176; on proposal to visit Alabama, 181.
Benedict, E., on cast iron pipes, 323.
Bernissart Colliery, pumping engine at the, 277.
Bessemer gold medal, presentation of, to Mr. J. D. Ellis, 38.
Bessemer ingots, cost of production in United States, 434.
Bessemer, Sir Henry, remarks on the presentation of gold medal to Mr. Ellis, 39; on universal rolling mills, 150.
Bibliography, mining and metallurgy, 436.
Bilbao, iron industry of, 424; iron ore mining at, 239.
Birkinbine, J., on the Buchanan magnetic rolls, 243; on the iron ore of Minnesota, 232.
Birmingham district, United States, 433.
Blair direct reduction process, the, 328.
Blast furnace, an American charcoal, 305; anthracite and coke in the, 295; the Eusley, Alabama, 309; the feasibility of using cheaper fuels in, 294; fine magnetites in the, 299; gases, 306; Mont St. Martin, 304; practice, American, 308; record of a charcoal, 305; in the Ural, 304.
Blasting, 289; large masses of iron and steel, 305.
Bliss, E. W., a new drawing-press, 331.
Blooms and billets, cost of producing, 435.
Blowing engines for steelworks, 347.
Bocket, H., on ventilators,
Bohemia, metallurgical statistics of, 408.
Boiler furnaces, the use of petroleum in, 265.
Boring mill, horizontal, 337.
Borneo, iron ore in, 227.
Bowron, W. M., on the cost of a ton of pig iron in the Sequachee Valley, 313.
Boyd, R. N., on the petroleum of Galicia, 264.
Bramwell, H., on roburite, 288.
Brauns, on iron ties and sleepers, 362.
Bresson, G., on dephosphorised steel, 348; on blast furnaces at Mont St. Martin, 304.
Bricks, ganister, 249; slag, 315.
Bridges, the use of ingot iron for, 365.
Bridge steel, 364.
Bristol, Tennessee, iron ores near, 233.
British Iron Trade Association, summary of statistics, 403.

Broome, R. S., on timbering in mines, 277.
Brough, Bennett H., on coal-mining in Spain, 251; on plotting colliery surveys, 291; on the utilisation of refuse fuel, 260.
Brullé, R., on the determination of sulphur in coal, 401.
Buchanan, magnetic rolls, the, 243.
Building purposes, iron for, 379.
Bunte, on the analyses of coal, 251.
Burke, Major, invitation by, to visit Alabama, 179; notes of, on the Alabama iron region, 205.
Burmah, iron ore in, 229.

C

Calorific value of coal, determination of, 250.
Canada, mineral statistics of, 414.
Carbonates, Hudson River, roasting, 245.
Carbon in iron, 386; determination of, 393.
Carbutt, E. H., on Report of Council, 9; vote of thanks to President, 203.
Carnegie, A., Chairman of American Reception Committee, 33; letter on the new iron region of Alabama, 206.
Carnot, A., on the determination of manganese, 394.
Cast iron, examination of, 323; influence of hydrochloric acid on, 390; pipes, 323.
Cast steel water jackets, 366.
Chalon, P. F., on electric lighting at the Ynishir Colliery, 278.
Charcoal blast furnace, an American, 305.
—— process, the Pierce, 262; proportion of ash and phosphorus in, 261; the world's consumption of, 262.
Chemical analysis of iron and steel, 391; composition of steel rails, 390.
Chesin, R. E., on iron ore in Mexico, 229.
Chicago, a new crucible steel blast at, 339.
China, mineral resources of, 415; natural gas in, 267.
Chrome ferro-manganese, 311; iron ore, artificial production of, 236; linings in open-hearth furnaces, 340; steel, 376.
Chromium, volumetric determination of, 398.
Clarke, R. W., on explosives, 285.
Clay, firebricks of, and asbestos, 249.
Clerc, M., on important repairs to a furnace in full blast, 306.
Coal, analyses of, 251; boring machine, a new, 274; calorific value of, determination of, 250; deposits of the South Appalachian field, 258; deposits of the Tennessee Valley, the, 257; determination of sulphur in, 401; discoveries in South Australia, 257; in Alaska, 257; industry of Belgium, 413; of United States, 431; in New South Wales, 256; in South Africa, 256; measures, new fossil resins from, 260; mines, the air of, 281; mining in Kentucky, 257; mining in Servia, 255; mining in Spain, 251; production of, in Great Britain, 403–406; in New South Wales, 407; in New Zealand, 407; in Belgium, 413; in Canada, 414; in China, 415; in France, 416; in Germany, 418; in Russia, 422; in Spain, 424.
Coalfields of Madagascar, the, 256.
Coke and anthracite in the blast furnace, 295; oven bottom, the Adams, 263; ovens, heating by natural gas, 263; screening machine, 263.
Collieries, air-compressing machinery at, 291; refilling, 274.
Colliery surveys, plotting, 292.
Comparison of basic slag and superphosphate, 351.
Composition of ferro-manganese and ferro-silicon, 314; of American pig iron, 315.
Compressed air for blast in cupola furnaces, 316.
Concentration of iron ore at Norberg, 240.
Consumption of charcoal, the world's, 262.

Cook, E. S., on anthracite and coke in the blast furnace, 295; on magnetite ores and foundry iron, 300.
Cooper, Joseph, on basic open-hearth steel, 109.
Copper, influence of, on the determination of iron, 401; influence of, on the tensile strength of steel. See *Ball.*
Corea, iron-making in, 330.
Corrosion of iron and steel, 355.
Cost of a ton of pig iron in the Sequachee Valley, 313; of making wheels, 323; of production of steel rails, 363; of pig iron, 312.
Council, Report of, for 1888, 3; retiring members of, 7.
Cowper, E. A., on testing machines, 196; on universal rolling mills, 148.
Cross-cut, rapid driving of a, 277.
—— tie, a standard metal, 362.
Crucible steel blast at Chicago, a new, 339.
Crystallisation of iron, 371.
Cuba, mining industry of, 415; manganese mines in, 415.
Cupola furnaces, compressed air for blast in, 316.

D

Daelen, R. M., on blowing engines for steelworks, 347; on rolling wire, 357.
Dahmen safety dynamite, 286.
Damascus steel, 353.
Darby, J. H., *paper* "On the manufacture of basic open-hearth steel."—Introduction, 78; coke and pig required, 78; experimental furnace employed, 79; construction of furnace, 80; use of basic material, 80; composition and character of charge, 81; illustrative diagram, 82; basic Bessemer process, 82; repairs, 82; "red-short" steel, 83; slag, 83; analysis of soft basic steel, 83; importance of suitable pig iron, 83. *Discussion:* Martel, B., 184, 187; Head, Jeremiah, 87; Whitwell, W., 87; Wailes, J. W., 89; Stoddart, C. J., 92; Martin, E. P., 94; Strick, G. H., 94; Gilchrist, P. C., 95; Head, John, 97; Paul, F. W., 99; Thielen, A., 102; Riley, James, 104; Richards, E. Windsor, 105; Head, Jeremiah, 106; Bell, Sir Lowthian, 108; Thielen, A., 108; Cooper, Jos., 109; President, 110; Darby, J. H., 110; Bell, Sir Lowthian, 111.
Daubrée, A., on meteorites, 237.
Delano, F. A., on rails, 359.
Demmin, on Damascus steel, 353.
Denby, natural gas in China, 267.
Dephosphorised steel, 348.
Deposits, coal, of the South Appalachian field, 258; of manganese ore, formation of, 235.
Derby, O. A., on meteorites, 237.
Determination of the calorific value of coal, 250.
Diller, J. S., on gehlenite in slag, 315.
Discoveries of coal in South Australia, 257.
Drilling machine, a new radial, 337.
Drills, rock, 240.
Driving of a cross-cut, rapid, 277.
Dunnington, F. P., on the formation of deposits of manganese ore, 235.
Durability of ganister bricks, 249.
Dynamite and safety cartridges, 287; Dahmen safety, 286.

E

Earth pressure in mines, measurement of, 291.
Eckardt, on chrome ferro-manganese, 311.
Edinburgh, meeting of Institute at, 5.

Edison magnetic ore separator, the, 244.
Edgar-Thomson Steelworks, a new rail train at the, 334.
Eggertz's carbon colour tests, 394.
Electric haulage, 276; lighting at the Ynishir Colliery, 278; lighting in mines, 279; welding, 356.
Electricity, application of, to mining, 273.
Electrolytic method as applied to iron, 400.
Ellis, J. D., election of, as member of Council, 3; presentation of Bessemer gold medal to, 38; remarks on receiving medal, 40.
Emmensite, 287.
Employment of explosives in fiery mines, 282.
Engine, pumping, at the Bernissart Colliery, 277.
Eusley blast furnaces, Alabama, the, 309.
Ewing, J. A., on the magnetisation of iron in a very strong field, 368.
Examination of cast iron, 323.
Explosions of gunpowder, premature, 290.
Explosions in fiery mines, employment of, 282; trials of, 284.
Exports. See *Imports*. From Sweden, 426; from United States, 432.
Eye-bars, steel, tests of, 378.

F

Fackenthal, B. F., on hollow pig patterns, 311.
Feasibility of using cheaper fuels in the blast furnace, 294.
Ferro-aluminium, 354.
Ferro-manganese, 354; and ferro-silicon, composition of, 314; chrome, 311.
Ferro-silicon and ferro-manganese, composition of, 314; economy of its use, 317; determination of silicon in, 397.
Fibre, iron, 371.
File steel, 374.
Fine magnetites in the blast furnace, 299.
Fire-bricks of clay and asbestos, 249; damp meter, 282.
Fires, the prevention of colliery, 281.
Fleitmann, Dr. T., on the volatility and mobility of iron atoms, 368.
Fletcher, H., on goaf stowing, 274.
—— L., on meteorites, 237.
Forging machine, a new, 331.
Forge, an oil-fired, 267.
Forsberg's hearth, 328.
Forty-ton shear, a, 332.
Foundry iron, magnetite ores and, 300.
Fractures of steel ingots and rails, 377.
France, production of iron and steel in, 416.
Frölich, C., on blast furnaces in the Ural, 304.
Fuel, liquid, in the manufacture of iron, 265; petroleum refuse as, 266; in the blast furnace, the feasibility of using cheaper, 294; utilisation of refuse, 260.
Furnace, Batho, 341; in full blast, repairs to a, 306.
Furnaces in blast in the United States, 429.

G

Galicia, petroleum of, 264; petroleum industry of, 409.
Ganister bricks, durability of, 249.
Ganström, G. A., on the concentration of iron ore at Norberg, 240.
Gas, natural, in China, 267; natural, in Indiana, 267; natural, in iron-making, 269; natural, in Meade County, Kentucky, 268.
Gases, blast furnace, 306; occlusion of, 385.

Gas-producer, the Ingham, 270.
—— testing and sampling, 401; valve, 345.
Gautier, F., *paper* "On the Thomasset testing machine."—Introduction, 184; Kirkaldy's and Styffe's machines, 184; multiple lever machines, 185; the ideal testing machine, 185; production of the pressure, 186; action of the pressure on the bar, 186; Kirkaldy's studies on pulling stress, 187; effect of length of bar, 188; want of uniformity, 188; effect of Thomasset machine on pulling stress, 188; table of tests made by the Thomasset machine, 190. *Discussion:* Adamson, Daniel, 191, 200; The President, 191; Wicksteed, J. H., 192; Cowper, E. A., 196; Walker, B., 197; Goodman, Mr., 197; The President, 199.
Gehlenite in slag, 315.
Genesis of petroleum, 263.
German imports and exports of iron, 420; iron industry. See *Schroedter;* lignite, 259.
Germany, iron trade statistics of, 417.
Gilchrist, P. C., on alloys of nickel and steel, 67; on basic open-hearth steel, 95; on thermal chemistry, 171.
Goaf stowing, 274.
Goodman, John, on testing machines, 197.
Götling, A., on coal mining in Servia, 255.
Gougé, J., on slag bricks, 315.
Gough, P. A., on the St. Croix range, Wisconsin, 234.
Graz Southern Railway, the basic steelworks of the, 342; the rolling mills of the, 333.
Grading of pig iron, the, 311.
Greece, manganese iron ore in, 235.
Greck, Colonel, obituary notice of, 222.
Grice, E. J., obituary notice of, 221.
Grundy, J., on the premature explosion of gunpowder, 290.
Gruner, E., on iron ore mining at Bilbao, 238.
Guinard, on the coalfields of Madagascar, 256.
Gunpowder, premature explosion of, 290.
Guns, 363.

H

HADFIELD, R. A., on alloys of nickel and steel, 68.
Hake, C. N., on bellite, 285; on dynamite, 286.
Hall, J. F., on alloys of nickel and steel, 56, 69.
Haulage, electric, 276.
Head, Jeremiah, on basic open-hearth steel, 87, 106; on universal rolling mills, 146.
——, John, on basic open-hearth steel, 97.
Heald, J., on the protection of iron from rust, 355.
Hearth, Forsberg's, 328.
Heating coke ovens by natural gas, 263; furnace, the Henderson, 344.
Henderson, heating furnace, 344.
Hengst powder, 288.
Henrotte, J., on the theory of centrifugal ventilators, 280.
Hewitt, Hon. A. S., invitation to meet in United States, 34.
Hildreth, R. W., on bridge steel, 364.
Hilton, J., on roburite, 288; on the Batho furnace, 341.
Hise, C. R. Van, on the iron ores of Michigan and Wisconsin, 230.
Hodgetts, E. A. B., on liquid fuel in the manufacture of iron, 265.
Hogg, T. W., on the determination of carbon in iron, 393; on the influence of copper on the determination of iron, 401.
Holgate, T. E., on the composition of ferro-manganese and ferro-silicon, 314.
Hollow pig patterns, 311.
Homestead Steelworks, universal mill at the, 335; rolling mill at the, 335; the open-hearth plant at the, 343.
Honl, A., on the prevention of colliery fires, 281.

Hopkinson, Dr. J., on the magnetisation of iron at high temperatures, 368.
Horizontal boring mill, 337.
Hot-blast stove, 310.
Howard, James, obituary notice of, 218.
Hudson River carbonates, roasting, 245.
Hudson, W. J., on American blast furnace practice, 308.
Hungary, iron trade statistics of, 410. See *Upper Hungary.*
Hunt, R. W., on fractures of steel ingots and rails, 377.
Husgafvel process, 325.
Hydrochloric acid, action of, on cast iron, 390.

I

ILLING, C., on iron-making in Corea, 330.
Imperial Institute, 6.
Imports and exports of Belgium, 413; of Germany, 420; of Russia, 423; of United States, 429; of United Kingdom, 404.
Improvements in mining appliances, 272; recent, in the production of water gas, 271.
Indiana, natural gas in, 267.
Ingham gas-producer, 270.
Ingot iron, the use of, for bridges, 365; manipulator, the Mason, 331. See *Steel.*
Ingots, fracture of, 377; the Williams process for making solid, 352.
Institute, invitation to the, to visit the United States, 33; to visit Alabama, 178.
Iron and steel, blasting large masses of, 305; corrosion of, 355; nomenclature of, 381; regulations for the delivery of, 381; international standards for the analysis of, 391.
Iron, atoms, volatility and mobility of, 368; carbon in, 386; gases in, 385; oxygen, influence of, on, 385; carbon in, determination of, 393; crystallisation of, 371; fibre, 371; microscopic examination of, 371; determination of, 400; for building purposes, 379; foundry, magnetite ores and, 300; influence of copper on the determination of, 401; liquid fuel in the manufacture of, 265; magnetisation of, at high temperatures, 368; in a very strong field, 368; protection of, from rust, 355; ties and sleepers, 362.
Iron-making, natural gas in, 269; in Madagascar, 329; in Corea, 330.
Iron ore, chrome, artificial production of, 236; concentration of, at Norberg, 240; in Borneo, 227; in Burmah, 229; in Mexico, 229; in New South Wales, 226; linings, chrome, in open-hearth furnaces, 340; mining at Bilbao, 239; in the Vermillion range, 234; in Michigan and Wisconsin, 230; near Bristol, Tennessee, 233; production of, 405; Bohemia, 408; Hungary, 411; Canada, 414; Cuba, 415; Germany, 418; Upper Silesia, 421; Lorraine, 421; Spain, 424; Sweden, 425; United States, 428.
Ironwork, rusting of, in tunnels, 390.
Ironworks, the Keystone, 309; the Riverside, 309.

J

JAMES, Thomas, obituary notice of, 219.
Japan, coal in, 422; imports of rails into, 422.
Jeffreys, E. A., obituary notice of, 220.
Jenisch, on a pulveriser for basic slag, 350.
Jenkins, William, election of, as Vice-President, 3.
Jerofeieff, M., on meteorites, 236.
Johnson, H., on blasting, 289.

K

KALAKOUTSKY, Major-General, obituary notice of, 215.
Keep, W. J., on ferro-silicon and the economy of its use, 317.
Kentucky, coal-mining in, 257.
Kern, S., on ferro-manganese, 354.
Keystone Ironworks, the, 309.
Kobb, F., on Styrian open-hearth steel, 343; on tool steel, 352.
Koninck, L. L. de, on the determination of carbon in iron, 393.
Kosmann, B., on limestone in Lower Silesia, 249.
Kunz, G. F., on meteorites, 238.
Krupp Steelworks at Essen, 345.

L

LA BEL, J. A., on the genesis of petroleum, 263.
Lake Superior iron ore mines, 431.
Lamin on bellite, 285.
Lamps, safety, 279.
Landreth, O. H., on the Pierce charcoal process, 262.
Lathe, turning and boring, 337.
Latschinoff, P., on meteorites, 237.
Ledebur, A., on carbon in iron, 386; on weak spots in iron test pieces, 375.
Ledent, A., on the pumping engine at the Bernissart Colliery, 277.
Lewes, V. B., on the corrosion of iron and steel, 355.
Life of rails, 361.
Lighting, electric, at the Ynishir Colliery, 278; electric, in mines, 279.
Lignite, German, 259.
Limestone in Lower Silesia, 249.
Linings, chrome iron ore, in open-hearth furnaces, 340.
Lisbonne, E., on guns,
Liquid fuel in the manufacture of iron, 265.
Lloyd, John, obituary notice of, 221.
Loadstone in Sweden, 227.
Lodge, Dr. O., on centrifugal ventilators, 280.
Lohmann, H., on trials of explosives, 284.
Long wire rope, a, 357.
Loonies water gas plant, the, 272.
Lorraine, iron trade statistics of, 421.
Lower Silesia, limestone in, 249.
Low, W., on the magnetisation of iron in a very strong field, 368.
Lürmann, F. W., on the use of water gas, 272.
Luxembourg, production of iron in, 419.

M

MACADAM, W. J., on new fossil resins from the coal measures, 260.
Machine, a new coal-boring, 274; a new forging, 331; a new radial, 337.
Machinery at collieries, air-compressing, 291; pipe-cutting and threading, 357.
Machines, universal milling, 334.
Madagascar, iron-making in, 329; the coalfields of, 256.
Magnetic ore separator, the Edison, 244; rolls, the Buchanan, 243; the Wenström, 243.
Magnetisation of iron at high temperatures, 368; of iron in a very strong field, 368.
Magnetite ores and foundry iron, 300.
Magnetites, fine, in the blast furnace, 299.
Manganese, determination of, 394; iron ore in Greece, 235; mines of Cuba, 415; ore, a Russian, 235; ore, formation of deposits of, 235; ore in Transcaucasia, 422.

Manufacture of iron, liquid fuel in the, 265.
Manufacturing steel from wrought iron, 339.
Manure, basic slag as, 349.
Martell, B., on alloys of nickel and steel for shipbuilding, 65; on basic open-hearth steel, 84, 87.
Martin, E. P., on basic open-hearth steel, 94.
Mason ingot manipulator, the, 331.
Masses of iron and steel, blasting large, 305.
Mayer, I., on dynamite and safety cartridges, 287; on various methods of firing shots, 289.
M'Millan, John, obituary notice of, 218.
Meade County, Kentucky, natural gas in, 268.
Measurement of earth pressure in mines, 291.
Medal, Bessemer gold, presentation of, for 1889, 38.
Meetings of the Institute, entertainment at, 6.
Meissel, E., on the comparison of basic slag and superphosphate, 351.
Members, deceased, in 1888, 3; new, list of, 1.
Mennier, S., on the artificial production of chrome iron ore, 236.
Meritens, M. de, on the protection of iron from rust, 355.
Mesuré, on the pyrometer, 251.
Meter, fire-damp, 281.
Meteorites, recent researches on, 267.
Method, a new pyrometric, 250.
Methods, various, of firing shots, 289.
Mexico, iron ore in, 229.
Michigan, iron ores in, 230.
Microscopic examination of iron, 371.
Mill, an ore-pulverising, 401.
—— universal, at the Homestead Steelworks, 335.
Milling machine, a new vertical, 333; universal, 334.
Mills, S. D., on an American charcoal blast furnace, 305.
Mineral statistics, 403.
Mines, accidents in Austrian, 409; electric lighting in, 279; fiery, employment of explosives in, 282; measurement of earth pressure in, 291; of Lake Superior, 431; timbering in, 277; ventilation of, 279.
Mining appliances, improvements in, 272.
——, application of electricity to, 273 cages, signalling from, 276.
Minnesota, iron ores of, 232.
Mobility and volatility of iron atoms, 368.
Moffat, E. S., on fine magnetites in the blast furnace, 299.
Mont St. Martin, blast furnaces at, 304.
Moore, R., on improvements in mining appliances, 272.
Morison, J., on air-compressing machinery at collieries, 291.
Moro, F., on the basic steelworks of the Graz Southern Railway, 342; on the rolling mills of the Graz Southern Railway, 333.
Morris, T., on basic slag, 350; on the crystallisation of iron, 371.
Movable platform for inclined planes in mines, 277.
Muck, F., on the influence of oxygen on iron, 385.
Münch, H., on blasting large masses of iron and steel, 305.
Murisier, O., on the Husgafvel process, 327.
Musgrave, John, obituary notice of, 218.

N

Nails of tinned sheet iron, 358.
Nasmyth, Dr. T. J., on the air of coal mines, 281.
Natural gas, heating coke ovens by, 263; in China, 267; in Indiana, 267; in iron-making, 269; in Meade County, Kentucky, 268.

New coal-boring machine, 274; crucible steel blast at Chicago, 339; drawing press, 331; forging machine, 331; fossil resins from the coal measures, 260; power presses, 331; pyrometric method, a, 250; rail train at the Edgar-Thomson Steelworks, 334; vertical milling machine, 333.
New South Wales, coal in, 256; iron ore in, 226; mineral statistics of, 407.
New Zealand, mineral statistics of, 407.
Nickel steel. See *Riley, J.*
Nitrogen in ingot iron, 383.
Noetling, Dr., on iron ore in Burmah, 229.
Nomenclature of iron and steel, 381.
Norberg, concentration of iron ore at, 240.
Nouel on the pyrometer, 251.
Nursey, P. F., on Dahmen safety dynamite, 286.

O

Obituary—Percy, Dr. John, 210; Pearce, Sir William, 213; Kalakoutsky, General, 215; Peacock, Richard, 217; Musgrave, John, 218; Howard, James, 218; M'Millan, John, 218; James, Thomas, 219; Jeffreys, E. A., 220; Lloyd, John, 221; Grice, E. J., 221; Greck, Colonel, 222; Roe, J. P., 222.
Occlusion of gases in iron, 385.
Odelstyerna, M., on chrome iron ore linings in open-hearth furnaces, 340.
Oil-fired forge, 267.
Olmstead, J., on roasting Hudson River carbonates, 245.
Open-hearth furnaces, chrome iron ore linings in, 340; at the Homestead Steelworks, Pittsburgh, 343; steel, basic, manufacture of. See *Darby, J. H.*; Styrian, 343.
Ore supplies of United Kingdom, 405; ores and slag, analyses of, 400. See *Iron, &c.*
Orton, E., ferro-silicon and the economy of its use, 317; on the natural gas in Meade County, Kentucky, 268.
Oswald, R P. W., on explosions in mines, 280.
Output, remarkable, 275.
Oxygen, influence of, on iron, 385.

P

PAPERS read in 1888, list of, 4.
Paris, decision of Council to meet at, 5.
Parker, William, on alloys of nickel and steel, 67.
Parry, J., on spectroscopy, 372.
Patterns, hollow pig, 311.
Pattinson, J., on thermal chemistry, 175.
Paul, F. W., on basic open-hearth steel, 99.
Peacock, Richard, obituary notice of, 217.
Pearce, Sir William, obituary notice of, 213.
Pease, Sir J., remarks on proposing vote of thanks to President, 30.
Peacoyd Steelworks, Pennsylvania, 344.
Pensky, B., on the behaviour of tempered steel, 376.
Percy, Dr. John, obituary notice of, 210.
Petroleum, genesis of, 263; in Venezuela, 265; of Galicia, 264; production of, in Austria, 408; in Galicia, 409; exports of, from Russia, 423; from United States, 432; refuse as fuel, 266; use of, in boiler furnaces, 265.
Phosphorus, determination of, 394; influence of arsenic on the determination of, 396; proportion of ash and, in charcoal, 261.
Pierce charcoal process, the, 262.

Pig iron, American, composition of, 315; cost of, 312; cost of a ton of, in the Sequachee Valley, 313; grading of, 311. See *Iron*.
Pipe-cutting and threading machinery, 357.
Pipes, cast iron, 323.
Pittsburgh, rolling mills at, 335.
Planes, inclined, moveable platform for, in mines, 277.
Plates, variations in the thickness of, 354.
Platform, moveable, for inclined planes in mines, 277.
Plotting colliery surveys, 292.
Plumacher on petroleum in Venezuela, 265.
Posewitz, Dr. T., on iron ore in Borneo, 227.
Pourcel, Alexandre, *paper* "On the application of thermal chemistry to metallurgical reactions." Introduction, 152; fundamental principles of thermal chemistry, 152; reaction in industrial chemistry, 152; ammonia soda, 153; calorimetrical investigations and results, 155; silicide of iron, 156; silicide of manganese, 156; phosphide of iron, 157; sulphides of iron and of manganese, 157; intermolecular combustions, 158; combustion of iron silicide, 158; combustion of iron phosphide, 159; combustion of iron sulphide, 162; conclusion, 163.—*Discussion:* Snelus, G. J., 165, 166, 168; the President, 166; Bell, Sir Lowthian, 167; Gilchrist, P. C.; 171; Bauerman, H., 173; Pattinson, J., 175; the President, 175; Bell, Sir L., 176; remarks in reply to discussion of his paper, 177.
Powder, Hengst, 288.
Practice, American blast furnace, 308.
Premature explosions of gunpowder, 290.
President, acknowledgment of vote of thanks by, 33; remarks on invitation to visit United States, 33; on presenting Bessemer medal to Mr. Ellis, 38; Mr. Riley's paper on alloys of nickel and steel, 71; on basic open-hearth steel, 110; on German iron industry, 122; on influence of copper on steel, 130; on universal rolling mills, 150; on thermal chemistry, 175; on testing machines, 199.
President's address, 13. Introduction, 13; the best Yorkshire iron trade, 14; reputation and properties of Yorkshire iron, 15; North-Eastern Railway experience of best Yorkshire iron, 16; experience of Brighton Railway, 16; development of machinery, 17; blast furnaces, 18; blowing engines, 18; live rollers, 19; shearing machines, 20; steam-hammers, 21; steam-cranes, 21; forging presses, 22; electrical welding, 24; water gas, 25; alloys, 25; the Forth Bridge, 27; ships, 27; railroad requirements, 28; technical education, 28; conclusion, 29.
Press, a new drawing, 331.
Presses, new power, 331.
Prevention of colliery fires, 281.
Process, basic open-hearth, 341; Husgafvel direct reduction, 325; the Blair direct reduction, 328; the Pierce charcoal, 262; Williams, of making solid ingots, 352.
Proctor, J. R., on the iron ores near Bristol, Tennessee, 233.
Production of chrome iron ore, artificial, 236; of pig iron, &c., see *Statistics;* of steel rails, cost of, 363; of water gas, recent improvements in the, 271.
Proportion of ash and phosphorus in charcoal, 261.
Protection of iron from rust, 355.
Pulveriser, for basic slag, 350.
Pulverising mill, 401.
Pumping engine at the Bernissart Colliery, 278.
Pyrometer, new, 257.

Q

QUAGLIO, M., on recent improvements in the production of water gas, 271.
Quicksand, sinking through, 239.

R

RADIAL drilling machine, 337.
Rails, 358; life of, 361; steel, cost of production of, 363; chemical composition of, 390; fracture of, 377.
Rail train, a new, at the Edgar-Thomson Steelworks, 334.
Rapid driving on a cross-cut, 277.
Raymond, Dr., letter of invitation to visit United States, 33.
Recent improvements in the production of water gas, 271; researches on meteorites, 236.
Record of a charcoal blast furnace, 305.
Refilling collieries, 274.
Refuse, petroleum, as fuel, 266; fuel, utilisation of, 260.
Reinhard, F. C., on the determination of iron, 400.
Reis, M. A. von, on the determination of phosphorus, 395.
Remarkable mine output, 275.
Repairs to a furnace in full blast, 306.
Researches on meteorites, recent, 236.
Resins, new fossils, from the coal measures, 260.
Richards, E. Windsor, on basic open-hearth steel, 105.
Riley, James, on basic open-hearth steel, 104; vote of thanks to President, 202.
——, James, *paper* "On alloys of nickel and steel."—Introduction, 45; visit to works in France, 45; conditions of manufacturing the alloy, 46; composition of nickel steel, 47; tests of steel, with varying contents of nickel, 48; properties of nickel steel, 49; breaking strain, elastic limit, and hardness, 49; torsional tests, &c., 50; corrodibility, 52; machining and punching, 52; theory of inventors as to formation of nickel alloys, 52; possible uses of alloys, 53; examples of uses, 53; adaptability for shafts and other marine forgings, 54; uses for shipbuilding and large structures, 54; conclusion, 55. *Discussion*: Hall, J. F., 56; Martell, B., 65; Gilchrist, P. C., 67; Parker, W., 67; Hadfield, R. A., 68; Carbutt, E. H., 70; Gény, M., 71; Samuelson, Sir B., 71; The President, 71; Riley, J., 72.
Rigaud, M., on the coalfields of Madagascar, 256.
Riverside Ironworks, the, 309.
Rivet steel, tests of, 377.
Roasting Hudson River carbonates, 245.
Roburite, 288.
Rock-drills, 240.
Roe, J. P., obituary notice of, 222.
Rogerson, John, on proposal to visit Alabama, 182; vote of thanks to Mr. Hewitt, 37.
Rolling mills at Pittsburg, 335; at the Homestead Steelworks, 335; of the Graz Southern Railway, the, 333.
Rolling wire, 357.
Rolls, the Buchanan magnetic, 243.
Ropes, A. B., on the composition of American pig iron, 315.
——, wire, 357.
Ruidant, C., on a movable platform for inclined planes in mines, 277.
Russia, mineral statistics of, 422; coal in, 423; imports of coal into, 423; exports of petroleum from, 423.
Russian manganese ore, 235.
Rusting of ironwork in tunnels, 390.
Rust, protection of iron from, 355.
Rziha, Ritter von, on rock-drills, 240.

S

SACK, Hugo, *paper* "On universal rolling mills for the rolling of girders and cruciform sections."—Introduction, 132; sections in process of rolling girders, 133; phosphoric iron girders, 134; rolling steel girders, 134; arrangement of universal

mill, 135; combination with existing mills, 136; principle of Sack's mill; housings, 139; rolling angle and cruciform sections, 140; arrangement of rolls, 141; finishing mill, 143; feed-rollers and tilting gear, 143; comparative weights of sections, 144; advantages of cruciform sections, 145. *Discussion*—Head, Jeremiah, 146; Cowper, E. A., 148; Bessemer, Sir H., 149; Riley, James, 149; the President, 150.
Safety cartridges, dynamite and, 287; lamps, 279.
Sampling and testing gas, 401.
Sandberg, C. P., on rails, 358.
Särnström, C. G., on the proportion of ash and phosphorus in charcoal, 261.
Schenk, A., on coal in South Africa, 256.
Schoenhof, J., on the cost of the production of steel rails, 363.
Schroedter, R., *paper* "On the progress made in the German iron industry since the year 1880."—Introduction, 112; Iron and Steel Associations, 112; production of coal, 1880–88, 113; coke production, 113; coke ovens, 113; Lürmann ovens, 114; production of iron ore, 114; Luxembourg and Lorraine ores, 114; analysis of minette ores, 115; amount of available ore and cost of production, 115; ores of Westphalia and Siegerland, 115; production of pig iron, 1880–88, 116; distribution of pig iron output, 117; condition of German blast furnaces, 117; production of finished iron and steel, 119; puddling furnaces, 119; Bessemer works, 120; imports and exports, 120; new fields, 121. *Discussion*—Thielen, A., 122; the President, 122.
Schwackhöfer, F., on the determination of the calorific value of coal, 250.
Screening machine, a coke, 263.
Scrutineers, appointment of, 1.
Securite, 289.
Separator, the Edison magnetic ore, 244; the Venström magnetic, 243.
Sequachee Valley, cost of a ton of pig iron in the, 313.
Servia, coal mining in, 255.
Shafts, winding from, 274.
Shear, a three-thousand-ton, 332; a forty-ton, 332.
Sheet iron, tinned, nails of, 258.
Shipbuilding, steel for, 366.
Shots, various methods of firing, 289.
Signalling from mining cages, 276.
Silicon in ferro-silicon, determination of, 397.
Sinking through quicksand, 239.
Slag, basic, as manure, 349; pulveriser for, 350; comparison of, and superphosphate, 351; bricks, 315; gehlenite in, 315; paving stones, 316.
Sleepers, iron ties and, 362.
Sleeper, a new steel, 362.
Smith, E. F., on the electrotype method as applied to iron, 400.
—— J. B., on wire and wire ropes, 357.
—— Josiah T., on iron ore supplies, 405.
Snelus, G. J., on thermal chemistry, 165, 166, 168.
South Africa, coal in, 256.
—— Appalachian field, coal deposits of the, 258.
—— Australia, coal discoveries in, 257.
Southern United States, iron industry of the, 432.
Spain, coal mining in, 251; mineral statistics of, 424.
Spectroscopy, 372.
Standards, international, for the analysis of iron and steel, 391.
Standard metal cross-tie, a, 362.
Statistics, United Kingdom, 403; Australasia, 407; Austria-Hungary, 407; Belgium, 412; Canada, 414; China, 414; Cuba, 415; France, 416; Germany, 417; Japan, 422; Russia, 422; Spain, 424; Sweden, 425; United States, 427.

St. Croix range, Wisconsin, 234.
Stead, J. E., on gas testing and sampling, 401.
Steel and its uses, 373; basic, manufacture of: see *Darby;* nickel: see *Riley, J.;* chrome, 376; dephosphorised, 348; eye-bars, tests of, 378; for files, 374; influence of copper on the tensile strength of: see *Ball;* open-hearth, production of, in Sweden, 427; rivet, tests of, 377; Styrian open-hearth, 343; tempered, behaviour of, 376; tool, 352; Damascus, 353; sleeper, 362; rails, cost of production of, 363; bridge, 364; for shipbuilding, 366.
Steelworks, basic, of the Graz Southern Railway, 342; open-hearth plant at the Homestead, 343; the Pencoyd, 344; the Krupp, at Essen, 345; the Wheeling, 346; blowing engines for, 347.
Stoddart, C. J., on basic open-hearth steel, 92.
Stones, paving, slag, 316.
Storrs, A. H., on winding from shafts, 274.
Stove, hot-blast, 310.
Stowing, goaf, 274.
Strick, G. H., on basic open-hearth steel, 94.
Stubbs, F., on the influence of copper on the tensile strength of steel, 129.
Styrian open-hearth steel, 343.
Sulphur, determination of, 396; in coal, 401; influence of, on Eggertz's carbon colour tests, 394.
Superphosphate, comparison of basic slag and, 351.
Svedberg, E., on the hot-blast stove, 310.
Swank, J. M., on natural gas in iron-making, 269.
Sweden, iron trade statistics of, 425; loadstone in, 227.
Swete, O. R., on safety lamps, 279.

T

Talbot, B., on the basic open-hearth process, 341.
Temperatures, magnetisation of iron at high, 368.
Tennessee Valley, coal deposits of the, 257.
Tensile strength of steel, influence of copper on. See *Ball.*
Terhune, R. H., on cast-steel water-jackets, 366.
Testing and sampling gas, 401; machines, recent, 379.
Test pieces, weak spots in ingot iron, 375.
Tests of bayonets and swords, 378; of rivet steel, 377; of steel eye-bars, 378.
Timbering in mines, 277.
Thickness of plates, variations in the, 354.
Thielen, A., on basic open-hearth steel in Germany, 102, 108; on iron consumption, 122.
Tholander, H., on the nitrogen contained in ingot iron, 383.
Three-thousand-ton shear, a, 332.
Thwaites, B. H., on an oil-fired forge, 267.
Tool steel, 352.
Trials, armour plate, 364; explosives, 284.
Tschbiell, A., on the rapid driving of a cross-cut, 277.
Turner, T., on Styrian open-hearth steel, 343; on tool steel 352.
Turning and boring lathe, 337.

U

United States, acceptance of invitation to meet in the, 5; invitation to the Institute to visit, 33; statistics of, 427.
Universal mill at the Homestead Steelworks, 335; milling machines, 334.
Upper Hungary, iron industry of, 411.
Ural, blast furnaces in the, 304.

Urquhart, T., on petroleum refuse as fuel, 266.
Use, ferro-silicon and the economy of its, 317; of ingot iron for bridges, 365; of petroleum in boiler furnaces, 265; of water gas, the, 272.
Utilisation of refuse fuel, 260.

V

Variations in the thickness of plates, 354.
Various methods of firing shots, 289.
Valve, gas, 345.
Venezuela, petroleum in, 265.
Venström magnetic separator, the, 243.
Ventilation of mines, 279.
Ventilators, centrifugal, theory of, 280.
Vermillion range, iron ores from the, 234.
Volatility and mobility of iron atoms, 368.
Volumetric, determination of, 398.
Votes of thanks to Council, 11; to the Institution of Civil Engineers, 202; the President, 202.
Vraug, C. A., on loadstone in Sweden, 227.

W

Wahlberg, E., on the volumetric determination of chromium, 398.
Wailes, J. W., on basic open-hearth steel, 89.
Wainwright, T., on the blast furnace, 295.
Walker, Benjamin, on testing machines, 197.
Walker, G. B., on electric haulage, 276.
Wallis, Mr., on electric lighting in mines, 279.
Warne, E., on the cost of making wheels, 323.
Warren, H. N., on the determination of carbon in iron, 393.
Water-gas plant, the Loomis, 272; recent improvements in the production of, 271; the use of, 272.
—— jackets, cast-steel, 366.
Watts, W., on roburite, 289.
Wedding, Dr., on the iron industry of Upper Hungary, 411; on the microscopic examination of iron, 371.
Welding, electric, 356.
Western United States, iron industry of the, 433.
West, H. H., on steel for shipbuilding, 366.
Wheeling Steelworks, the, 346.
Wheels, the cost of making, 323.
Whitfield, J. E., on gehlenite in slag, 315.
Whitwell, W., on basic open-hearth steel, 87.
Wicksteed, J. H., on the Thomasset testing machine, 192; on the Emery testing machine, 379.
Williams, H. J., on the determination of silicon in ferro-silicon, 397.
—— R. Price, on the coal question, 406.
Winding from shafts, 274.
Wingham, Arthur, on the influence of copper on the tensile strength of steel. See *Ball.*
Winkler, Prof., on the world's consumption of charcoal, 262.
Wire and wire ropes, 357; rolling, 357; rope, a long, 357; strength of, 374.
Williams' process of making solid ingots, 352.
Wisconsin, iron ores in, 230; St. Croix range in, 234.

Wood, H., on coal in New South Wales, 256; on iron ore in New South Wales, 226.
Woodbury, C. J. H., on electric welding, 356.
World's consumption of charcoal, the, 262.
Wrightson, Thomas, remarks on services of Council, 10.
Wrought iron, manufacturing steel from, 339.

Y

Ynishir Colliery, electric lighting at the, 278.

Z

Zulkowsky, K., on an ore-pulverising mill, 401.

THE END.

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